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Civil Aeronautics Bulletin No. 27
SEPTEMBER 1940

# Pilots' Airplane Manual

By N. O. Anderson
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UNITED STATES
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# PREFACE

This manual has been prepared for the purpose of familiarizing the student pilot with the structure, maintenance, and rigging of aircraft. It is primarily designed to serve as a textbook in the controlled Restricted Commercial ground school course of the Civilian Pilot Training Program, and as such is used in conjunction with CIVIL AERONAUTICS BULLETIN NO. 26, AERODYNAMICS FOR PILOTS. The treatment of the subject matter in the manual is of a nontechnical nature, providing factual information from a generalized point of view. In use it may be supplemented by reference to manufacturers' manuals and other textbooks if more detail is desired.

Considerable space has been given to seaplane floats and hulls. Such portions are included for the instruction of those students who are being trained in seaplane operation.

At the end of each chapter is a list of questions on the subject matter presented in the particular chapter. It is felt that these questions will be of material aid to the student in reviewing the work accomplished.

Acknowledgment is made to the Army Air Corps and to the Navy Bureau of Aeronautics for their cooperation in making available material from certain of their publications. Acknowledgment is also made to the University of Alabama for making available its facilities in connection with the actual writing of this and other pilot training texts prepared during the summer of 1940.

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# Chapter I.—STRESSES ON AIRCRAFT STRUCTURES

It is common practice in much engineering work to figure how much load the structure will have to carry and then to build it strong enough to carry many times this load. It is often possible in such structures as buildings or bridges to use materials that would normally be unsuitable for the purpose by simply increasing the size and hence also the weight of the parts. In the manufacture of airplanes this procedure cannot be followed, for the aircraft designer must always keep in mind the combination of adequate strength with light weight.

For this reason great care must be exercised in the selection of material and in the design of airplane structures so as to secure a complete unit which will combine the qualities of adequate strength with light weight. Insofar as possible careful analysis must be made in the design of aircraft of the stresses experienced by each structure and part, and materials for each part of the structure are therefore carefully chosen which exhibit the strength characteristics specifically adapted to the stresses developed in the specific member or part.

Not only in the manufacture but also in the maintenance of aircraft is it important that the stresses be understood, as failure to do so might lead to the neglect of the essential repairs or replacements or introduction of weaknesses as a result of such repairs and replacements. The pilot should have a fundamental knowledge of the stress problems facing both the engineer in designing the airplane and the mechanic in maintaining it. This chapter gives a brief analysis of the various stresses which may be developed in aircraft structures.

## EFFECT OF EXTERNAL FORCES

When a solid body is acted upon by an *external force,* internal resisting forces are developed in the body which balance the external applied force. The internal forces acting between adjacent particles of the body are called stresses. The unit stress is the amount of internal force per unit area and is measured in pounds loading per square inch of cross-sectional area.

The body acted upon by an external force changes its shape; i. e., is deformed. The deformation produced is called strain. Tensile strain is measured in inches elongation per inch length of material.

## KINDS OF STRESSES

Depending upon the arrangement and direction of the external forces, the stresses produced in a body may be: Tensile stresses, compressive stresses, shearing stresses, bending stresses, torsional stresses, combined stresses.

Each part of the structure of the airplane may be subjected to one or more of these kinds of stresses. Even though the integral parts of the airplane may have nonuniform cross sections, it suffices here to illustrate these stresses by considering the external forces as acting on a bar of uniform cross section.

## TENSILE STRESSES

When the external forces act upon the ends of a bar in a direction away from the ends they are called *tensile forces.* They exert a pull on the fibers of the material.

Thus in (*a*) figure 4 two tensile forces, each equal to P, act upon the ends of a bar having a cross-sectional area A. MN is an imaginary plane normal (at right angles) to the axis of the bar. If the two parts of the bar be imagined separated, as shown in (*b*), the equilibrium of each part will be maintained if external forces equivalent to the resisting stresses are applied as shown. These resisting stresses act normal to the cross section, A, and are in each case opposite in direction to the force, P, on the respective part.

When the forces are applied in the opposite direction, i. e., toward the center, the term compression is used. Let $S$ be the stress of tension or compression which acts normally on any cross section of a bar having the cross-sectional area $A$. The total stress on the section is then $SA$, which is uniformly distributed over an area $A$. When the force $P$ acts along the axis of the bar:

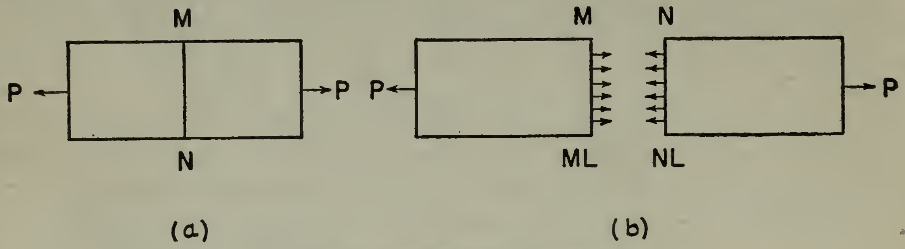


Figure 1.—Action of tensile forces.

$$P=S\times A$$

Hence, one of the quantities may be computed when the other two are given. If the tensile strength $S$ of a bar of wood is 10,500 pounds per square inch and the bar is subjected to a pull $P$ of 84,000 pounds the cross-sectional area $A$ required will be

$$A=\frac{P}{S}=\frac{84,000}{10,500}=8 \text{ square inches.}$$

## COMPRESSIVE STRESSES

The general appearance of a short column which has been stressed to failure by compression is illustrated by figure 2. When the compressive stress is uniformly distributed over the cross section, failure will occur when the intensity of stress reaches a critical value. If the material is ductile it will flow and thus change its position, whereas if it is brittle it may shear and rupture. To illustrate, step on a piece of soft lead and compare the results with that obtained by crushing a cube of ice. If the load is removed the material makes only a partial return to its original position, even though highly elastic, and the material will be permanently deformed. This is called *plastic* failure since it involves plastic deformation of the material. The critical stress at which such failure occurs is usually the compression yield point of the material.

## SHEARING STRESSES

When two equal and opposite forces act at right angles to the axis of a bar and are very near together they are called *shearing forces*, and tend to cut or shear the bar. The action of the forces is similar to that of a pair of shears, from which analogy the name is derived. Shearing stresses act parallel to and across the sectional area, as indicated by figure 3 which shows a rivet under single shear and double shear.

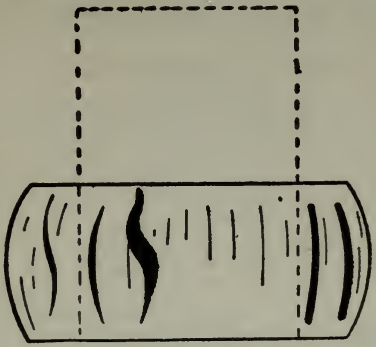
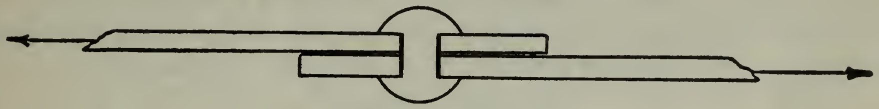
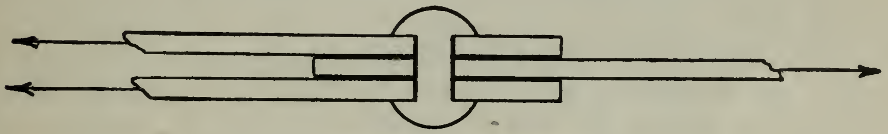


Figure 2.—Failure of material due to compression.



SINGLE SHEAR



DOUBLE SHEAR

Figure 3.—Shearing forces on a rivet.

## BENDING STRESSES

When a bar is fixed at one end and a load or external force is applied at the other end in a direction at right angles to the axis, a rather complicated reaction results. The bending action of the applied load or the *bending moment* at any point along the beam is measured by the product of the load and its distance from the particular beam section. The bending moment is at a maximum at the point of support in this type of beam which is known as a *cantilever* beam.

In the common case of a beam supported at both ends with a concentrated load in the center of the span, the maximum bending moment occurs at the center of the span and, other factors being equal, the beam if overloaded will rupture at that point.

## TORSIONAL STRESSES

When applied forces result in twisting moments which cause a member to twist or rotate about an axis, *torsional* deformations occur. If a long tube is fixed at one end and a twisting moment applied at the other, the individual longitudinal elements of the tube will assume a spiral form similar to the threads on a screw. Under small twisting moments, the deformation or angle of twist is proportional to the twisting moment up to the elastic limit of the material. Beyond the elastic limit the angle of twist increases more rapidly than the twisting moment, and when the force is removed a permanent set remains in the material.

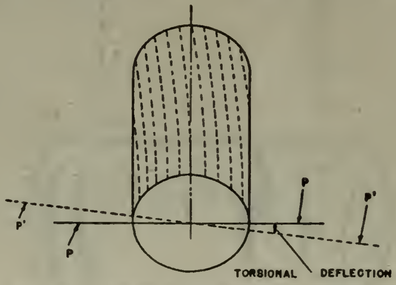


**Figure 4.—Torsional stresses in a round bar.**

The primary stress in material under torsion is a shearing stress. The strain, if the material is not stressed beyond the elastic limit, is inversely proportional to the shearing modulus of elasticity of the material.

## ELASTIC LIMIT

As has been previously stated, when a member is subjected to gradually increasing load it is deformed, and up to a certain limit the deformation or strain is proportional to the applied load. The *elastic limit* is defined as that unit stress at which the deformation begins to increase at a faster rate than the applied load. The elastic limit is also termed the "proportional limit."

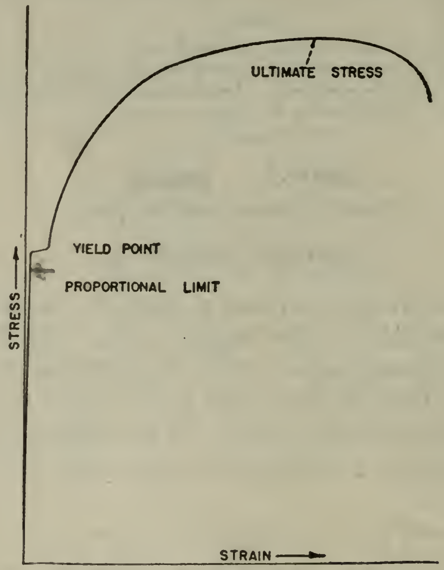


**Figure 5.—Stress-strain diagram.**

## YIELD POINT

The *yield point* is the loading which causes the extension of a piece of metal under tensile test to increase without increase of load. If the stress on a piece of metal is gradually increased after the yield point has been reached, a sudden drawing out or elongation greater than the entire amount of elastic extension will be noticeable.

## ULTIMATE STRENGTH

*Ultimate strength* is the term used to designate the highest unit stress that a member can sustain. This occurs at or just before failure or rupture of the material. The ultimate strength of materials is the basis of structural-strength analysis in this country.

## FACTOR OF SAFETY

The ratio of the ultimate strength of a member to the maximum probable load on the member is the *factor of safety.* For example, assume that a steel column under its maximum probable load is stressed 20,000 pounds per square inch cross-sectional area in compression. If the column will collapse at a stress of 30,000 pounds per square inch, the factor of safety is $\frac{30{,}000}{20{,}000}=1.5$.

## REDUCTION OF AREA

In a member ruptured by tension, a *reduction in area* of the cross section at the point of rupture will be observed. This reduction in area is a characteristic of tension failures. The percentage of reduction in area from the original cross-sectional area varies according to the material, being greatest for soft, ductile materials and least for hard, brittle materials.

## COLUMN ACTION AND COMPRESSION

A compression member having a high ratio of length to width or thickness will fail under a stress much less than the yield point. When a load reaches a certain magnitude the whole member will bend laterally and act very much like a spring. If the load is slightly reduced the member will return to its original position and examination will show no injury or deformation. This type of failure is called *elastic failure or buckling*

When a long column is loaded so that it fails elastically and bends laterally, if the deflection is permitted to continue, the compressive stresses on the concave side of the deflected column will eventually pass the yield point of the material and plastic failure will ensue. Once plastic failure has started, removal of the load will not suffice to return the member to its original position

The majority of columns used in conventional structures are of intermediate length, and their failures will show a combination of the characteristics of the extremely long and the extremely short columns. The prediction of the critical load for extremely short and for extremely long columns is a relatively simple matter, but for columns of intermediate length prediction of the critical load must depend on empirical curves and formulæ the result of extensive static tests.

Other factors which influence column action are the condition of the ends, the homogeneity of the member, stiffness, and the position of the load with respect to the center of resistance of the column.

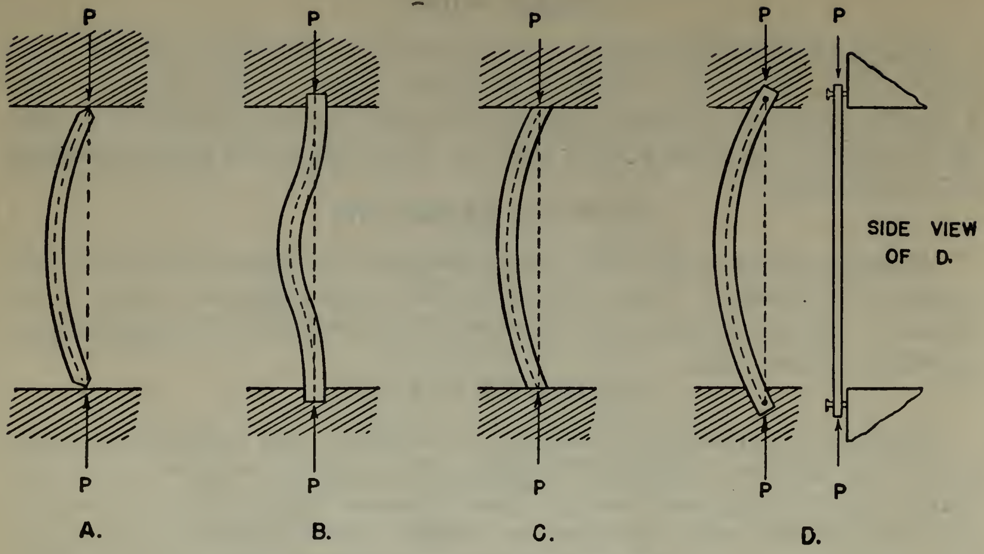


Figure 6.—Columns under compression loads.

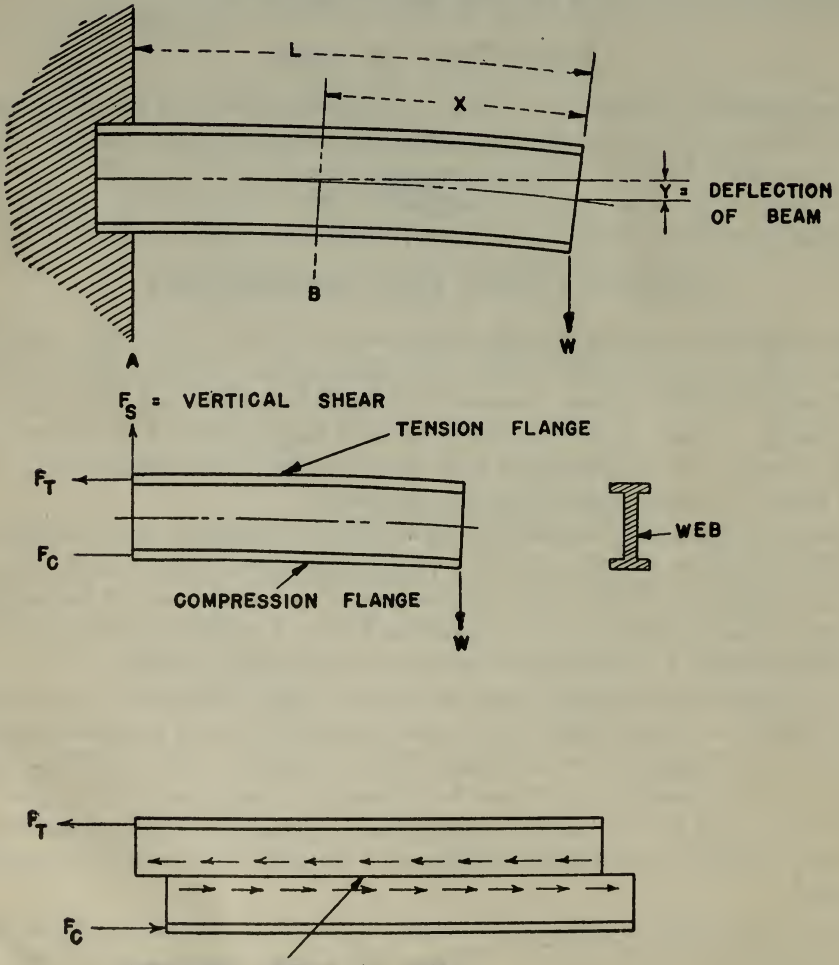


Figure 7.—Bending of a beam.

There are four types of end conditions which are common: (*a*) Round end, where the end is free to rotate; (*b*) fixed end, where the axis of the column has a fixed position near the column end; (*c*) square end, where the end of the column and the abutting surface are perpendicular to the axis; and (*d*) pin end, where rotation of the column end is permitted in one plane only.

Figure 9 illustrates the behavior of a column under these different end conditions. These theoretical conditions are not realized in practice. In the round and pin-end column, friction at the bearings produces restraint; on the other hand, no ordinary support is sufficiently rigid to produce a fixed end.

Owing to the uncertainty regarding: (*a*) Conditions at the ends, (*b*) action between parts, and (*c*) the position of the load with respect to the axis of the column, theoretical analysis of column action is approximate only. The main reliance of the designer is the information obtained from tests. This is particularly true of built-up columns which may fail by twisting or buckling.

## BEAMS AND BENDING

The primary function of a *beam* is to carry a *bending load.* Consider the elementary case of the cantilever beam such as is used in cantilever monoplanes in figure 7.

The beam is fixed at $A$ and loaded by a weight $W$ which produces a bending moment at point $B$ equal to $Wx$. For example if $W = 100$ pounds and $x = 50$ inches the bending moment at $B$ is $100 \times 50 = 5{,}000$ inch-pounds.

If the beam be cut across at $B$, the forces $F_t$, $F_c$, and $F_s$ must be applied to hold the beam in equilibrium. $F_t$ is the tension force which is carried by the upper flange of the beam. $F_c$ is a compression force which is carried by the lower flange of the beam. $F_s$ is the force producing vertical shear in the beam. It is shown in textbooks on mechanics that the vertical shear is equal to the horizontal shear, so called because beams are ordinarily used in a horizontal position. As indicated in figure 10 the horizontal shear produces shearing stresses in the web of the beam.

All members subjected to bending moments, regardless of the number and arrangement of the supports, are subjected to tension stress on one side of the member, compression stresses on the other side of the member, and shearing stresses along the longitudinal axis of the member.

The resistance of beams to bending forces depends upon the distribution of the material across the beam section. It is obvious that a beam of rectangular section will carry a greater load when placed on edge than when placed flat. The material which is close to the neutral axis contributes very little to the strength of the beam. (The neutral axis is the line which separates the portion of the cross section in tension from the portion in compression.) In order to save weight and use material in beams efficiently, the beam section frequently is designed so that a large part of the material is in the flanges of the beam and the web or portion of the beam close to the neutral axis is made thin. The shearing stresses (which are of maximum intensity at the neutral axis) are the limiting factors in reducing the thickness of the web.

## COMBINED BENDING AND COLUMN ACTION

Many structural members of the airplane are required to resist axial compression loads combined with bending moments. A beam supported at the ends and loaded in the center as in figure 8 will deflect an amount $y$. If subjected then to an axial load of compression $P$, the beam must resist not only the axial load of compression but an added bending moment equal to $Py$.

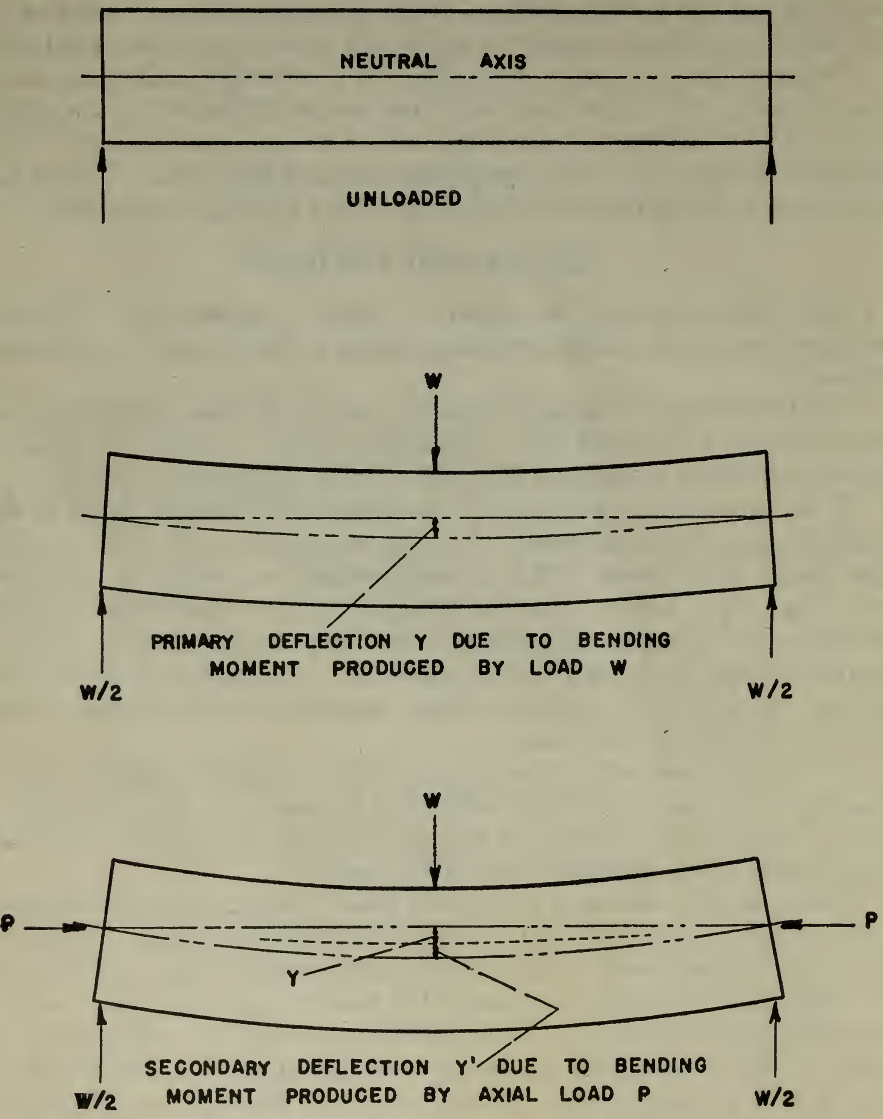

NEUTRAL AXIS
UNLOADED
W
PRIMARY DEFLECTION Y DUE TO BENDING MOMENT PRODUCED BY LOAD W
W/2
W/2
W
P
P
Y
SECONDARY DEFLECTION Y' DUE TO BENDING MOMENT PRODUCED BY AXIAL LOAD P
W/2
W/2

Figure 8.—Axial loads on beams in bending.

The added bending moment $Py$ produces further deflection $y'$ and the deflection continues to increase until a state of equilibrium is reached. The bending moments $Py'$ and $Py''$ are called secondary bending moments and greatly influence the ultimate strength of the member.

In most engineering fields the design of members subjected to combined bending and axial loads is accomplished by making conservative assumptions which permit members to be designed with little more difficulty than is involved in the investigation of a simple beam. Such assumptions involve making the members heavier than is necessary, and since economy of weight is of great importance in airplane design the aeronautical engineer is not satisfied with their use. A major factor leading to better and more efficient airplane structures has been the development of precise methods of calculating accurately the crippling loads of beams subjected to axial loading.

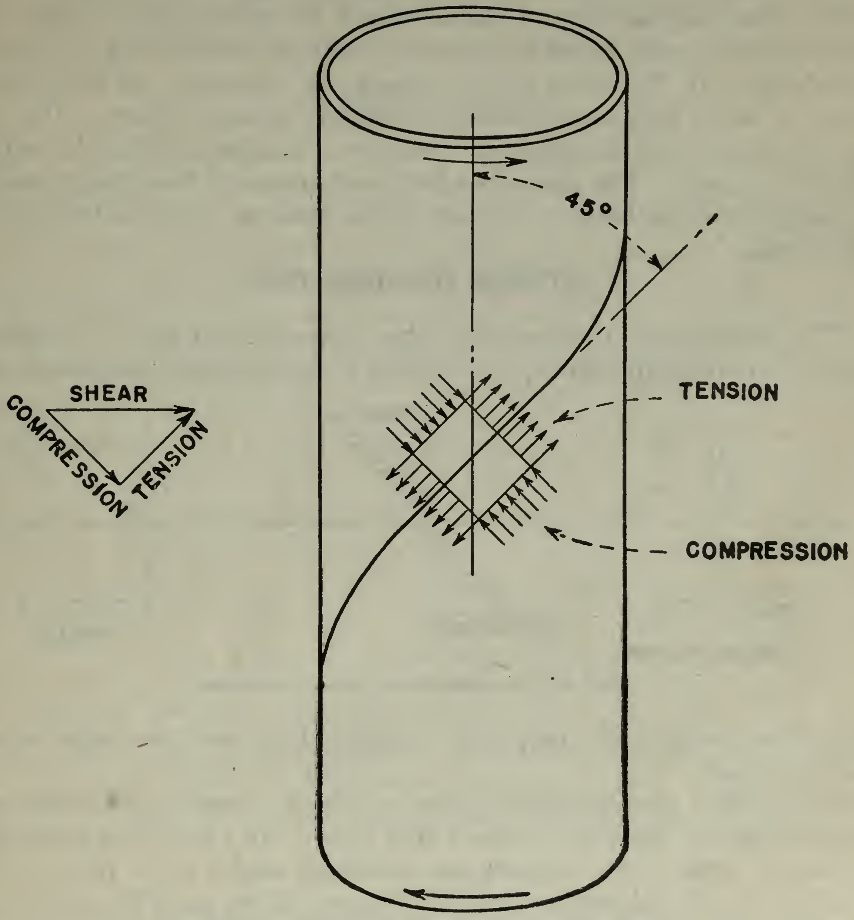


Figure 9.—Combined stresses in torsion in thin wall tubes.

## COMBINED SHEARING AND BENDING STRESSES

Bolts, pins, and rivets are members which are frequently designed to resist shearing stresses only. Although the principal stress in members in pure torsion is a shearing stress, in thin walled tubes subject to torsion local failure may occur by compression, the combination of stresses being as indicated in figure 9.

Pure torsion seldom occurs in members in an airplane structure as the loads are generally so applied as to produce bending in the member as well as torsion. Axle tubes, crankshafts, and the main members of movable control surfaces are examples of structural parts subjected to combined torsion and bending. Landing gear members, in addition to torsion and bending, are

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also subjected to axial loads. In many cases the combination of stresses may be extremely complicated and corrrespondingly difficult for the designer to analyze.

## REVERSAL OF STRESS AND FATIGUE

Many parts of the airplane structure are subject to vibration, repeated impact loads, and reversals of loading. Fatigue resistance is the property of metals which enables them to withstand repeated applied loads and reversals of loading. Fatigue failures are characterized by microscopic changes in the structure of the metal which develop into incipient cracks and final fracture of the material. If the stress is low enough, the repetition of the loading or reversal of stress may be continued indefinitely without failure. The highest stress which permits this indefinite repetition of loading is called the endurance limit of the metal. The endurance limit is determined from long period tests on vibration test machines. It is always less than the stress at the yield point of the metal.

## STRESS DISTRIBUTION

The distribution of stress over the cross-sectional area of a structural member is of vital importance since rupture of the material may occur at a point of maximum stress even though the average stress over the entire section is within safe limits.

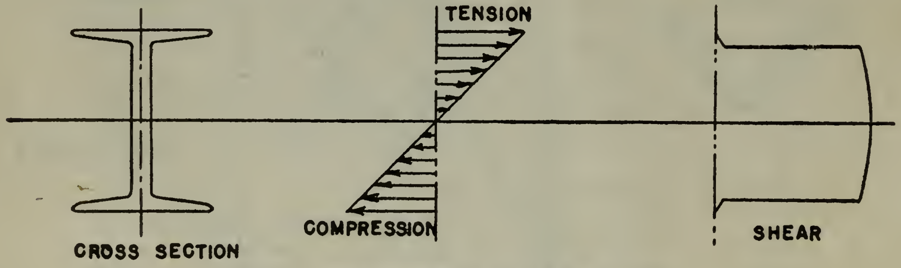

Figure 10.—Stress distribution across a beam section.

Local stress concentration occurs at sharp corners and where sudden changes in section shape of members take place. To avoid local stress concentrations, all corners are rounded and reentrant angles given fillets. Surface conditions due to tool marks, scratches, forging defects, and file marks localize stresses and are particularly effective in hastening fatigue failure; small initial cracks spread rapidly in members subject to vibration due to localization of stresses. The spread of cracks in cowling may sometimes be stopped by drilling a round hole at the end of the crack. The increased radius of the hole decreases the stress localization and may prevent further failure from fatigue.

The theoretical methods of calculating the distribution of stress in members are almost wholly dependent upon the assumption that the material is perfectly elastic, i. e., that the deformations or strains are exactly proportional to the stresses. We know, however, that when materials are stressed beyond the elastic or proportional limit this relationship does not hold true. Nevertheless, the laws governing the behavior of perfectly elastic materials under load are of immense value to the engineer and his chief reliance in structural design.

For very short columns subjected to simple compression, and members subjected to simple tension such as wires and tie rods, the stresses are uniformly distributed across the section. In beams subjected to simple bending, the tension and compression stresses are distributed across the section as indicated in figure 10. The shear stresses in beams are greatest in the web.

Built up sections of thin sheet present a problem to the engineer so complex that a theoretical analysis of the stress distribution is at best only approximate. Such sections may fail by twisting or buckling rather than by simple tension or compression, and local stress concentration plays an important role in such failures.

## STRESS ANALYSIS

The aircraft engineer has an unusually difficult time in analyzing the stresses that will actually occur in a structure, these difficulties being of a twofold nature. The first trouble is in determining with a satisfactory degree of accuracy the external loads to which an airplane is subjected in flight and in take-off and landing. The second trouble is that even when the external loads are known, the science of structural analysis is frequently not advanced sufficiently to permit an exact determination of the strength of the structure itself. In many structural parts and shapes the laws of stress distribution are so complex that they still remain something of a mystery.

Static testing is the means used by the engineer to fill in the gaps in his knowledge due to the failure of theoretical methods of stress analysis to furnish all the answers to questions regarding structural strength. Parts or assemblies are subjected to gradually increasing loads simulating, so far as possible, the load conditions in flight. A study of the deflection of the parts under load and the determination of the crippling load or ultimate load yields information which becomes the basis for the design of the final structure. Where large numbers of tests on similar parts are available, it is frequently possible to construct empirical formulae which will predict the action under load of any structure within a given classification. It is in this manner that the curves which enable the engineer to predict the strength of short columns have been derived, and the method is applied to countless other parts of the airplane structure.

## DESIGN LOADS

The airplane designer is greatly troubled when he considers the problem of external loads to which the structure is subjected in flight, take-off, and landing. When these loads are not accurately known, assumptions and possible errors must always be on the conservative side so that if the worst comes to pass, the structure will stand the test. It must be obvious that this method in many cases leads to overweight and inefficient structures.

To a considerable degree, advance in airplane performance is linked with the extensive program of research being conducted by the National Advisory Committee for Aeronautics to determine more accurately the actual loads imposed on aircraft under service conditions. As accurate data become available, the design load requirements for aircraft are amended, and the airworthiness requirements of Civil Air Regulations which prescribe the design loads for civil aircraft, are changed.

The restricted amount of time available for this course of instruction does not permit a detailed study of strength requirements for airplane structures; however, for those students who desire more information on this subject, the study is recommended of Civil Air Regulations, Part 04, Airplane Airworthiness.

A *proof load* is a load less than the ultimate load, or the crippling load, which is applied to a structure to determine its airworthiness without permanently damaging it. The cost of a static test to destruction of a large airplane of new design may be prohibitive, and yet assumptions are frequently necessary in design which must be tested by observation of the action of the structure under load. In these cases a study of the deflections of the structure under a gradually increasing proof load may give information leading to a final determination of its safety.

The structure, if it satisfactorily withstands the test of a proof load, may be placed in service. If the proof loading is carefully conducted, minor failures in parts of the structure may be corrected and the structure subsequently passed as satisfactory, and the loss incident to a static test to destruction or failure of the structure in flight avoided.

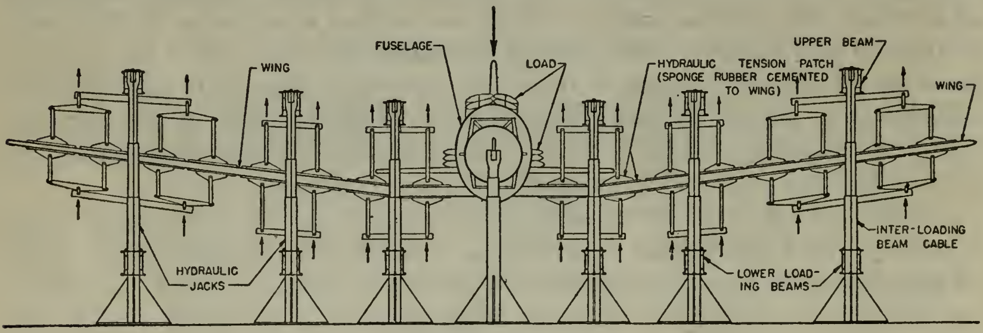

Figure 11.—Proof load test set-up.

Figure 11 illustrates a proof loading test. A load consisting of bags of lead shot and lead bars is placed in the fuselage, a similar load is placed on the tail, and a load applied to the engine mount. These applied loads are so adjusted as to be in equilibrium about the center of gravity of the airplane as loaded for flight.

By means of the hydraulic control panel in the foreground, upward acting forces are applied to the wings by a system of hydraulic jacks until the entire applied load on the fuselage is supported by the wings.

Proper distribution of the load along the span, along the chord, and between the upper and lower surfaces of the wings is secured by adjustment of the relative lengths of a series of lever arms through which the forces are applied to the wing surface.

The forces are transmitted to the wing surface by means of a sponge rubber patch which is fastened to the wing cover by a cementing compound.

## *Questions*

1. Define: stress, unit stress, deformation, strain, unit strain.

2. List five parts of an airplane which will be under tensile stress when the plane is in flight.

3. Sketch a tripod type landing gear, and indicate which parts are under compression stress when the plane is on the ground.

4. What is plastic failure? Failure to return to shape — yield point

5. What is elastic limit?

6. Distinguish between elastic limit and yield point.

7. What term would be used to describe the physical properties of a material whose ultimate strength and elastic limit are the same?

8. Define factor of safety.

9. What stresses are found in a uniformly loaded beam?

10. How does fatigue failure show up?

11. How is stress concentration prevented?

12. What effect does a scratch on the surface of a part have on its ability to resist fatigue?

13. Define stress analysis.

14. Why is stress analysis of aircraft parts sometimes difficult?

15. How may the strength of aircraft parts be determined, when stress analysis is impossible?

16. How are design loads determined?

17. What is a proof load?

18. How may the ductility of a material be estimated from a tension break?

19. What causes fatigue?

# Chapter II.—AIRPLANE MATERIALS

A wide variety of structural materials is required in the manufacture of aircraft. As was brought out in the preceding chapter, this is made necessary by the varying needs with respect to strength, durability, and deterioration of the specific structures or parts. In this chapter a brief discussion of the majority of these materials is given. The pilot is in full charge of the airplane during flight and he is frequently called upon to check its condition prior to and during the flight. Understanding of characteristic materials is necessary if he is to do this intelligently.

## WOODS

While the modern tendency is undoubtedly towards metal aircraft, it will be a long time before wood is discarded entirely as a structural material, particularly on small airplanes, and especially on small airplanes in civil aviation and in the case of forced construction of aircraft during a national emergency. There are two important reasons for this, namely, cost and weight. Wood beams and ribs can be made by carpenters, cabinetmakers, etc., and require little more than a few simple hand and power tools. Metal beams and ribs require large expenditures in tools and equipment such as dies and power machines to stamp out and shape the materials.

Designs frequently change and it is next to impossible to use parts manufactured for one airplane in another, even though the variation may be slight. Furthermore, it is difficult to use metal in a small structure so as to take advantage of its full strength, the result being that a wooden structure equally strong will almost always weigh less than metal. (This condition is rapidly changing with newer designs.)

Wooden beams and ribs can be repaired and spliced in the field, whereas metal beams and ribs generally necessitate waiting for the required parts to be sent from the factory.

Wood is one of the most common materials used for structural purposes and has many advantages over other materials. There are, however, such a variety of factors entering into a consideration of its use that only by careful study can one make an intelligent selection of the proper kind of wood for any specific purpose. In aircraft construction the wood must combine at the same time the characteristics of lightness, strength and stiffness and while practically all woods have at some time or other been employed, the rapid advance in design and development in the past few years has reduced the selection to approximately seven species, i. e., spruce, ash, fir, mahogany, balsa, hickory, and pine.

Spruce is used in the manufacture of struts, wing beams, and in float and hull construction.

Ash is used in the manufacture of longerons, float chines, keel members, tail-skids, cabane struts and bearing blocks.

Fir is a satisfactory substitute for spruce.

Mahogany is used for veneer covering, rib webs, and in deck, bottom and bulkhead planking of floats and hulls (if of wooden construction).

Balsa is used in the manufacture of fairing strips and streamlining.

Hickory is used in the manufacture of landing gear struts and wing panel bows.

White Pine is used in the manufacture of patterns and forms.

Compared with the other materials, certain woods have remarkable strength for their weight. Spruce in tension is 2.6 times as strong as steel for the same weight and length and, in compression, twice as strong. The strength of wood, however, is affected by many factors, included among which are: structure, kind, age when felled, method of sawing, moisture content, seasoning, defects, amount of sapwood, and heartwood. It will be seen readily that these influences make aircraft wood of proper selection a fairly expensive material and one with which the most careful judgment must be exercised.

The comparative width of annual rings, and the direction and arrangement of the cells and fibers are the causes of the *grain* of wood. Thus, trees of rapid growth having wide annual rings produce coarse-grained wood, while those of slower growth produce wood with narrow rings, or fine grain. When the wood elements are straight and run parallel to the pitch, the wood is said to be straight-grained. Often, however, the elements are twisted and around the axis of the tree, causing spiral grain. Frequently in cypress and gum, several rings of fibers are oblique to the axis of the tree in one direction whereas the next layer of elements is oblique in the opposite direction. Such wood is *cross-grained. Wavy grain* is caused by large undulations in the wood elements, generally on radial surfaces; *curly grain* by small undulations. Oak, ash, cherry, birch, and maple often exhibit curly or wavy grain.

Since straightness of grain is of great importance in wooden beams and tension members, *careful examination should be made to eliminate cross-grained or spiral-grained timbers.* The splitting radially of a small stick is about the only safe test for detecting spiral grain.

Careful inspection should be made to detect the following defects of wood: knots, checks, ring shakes, heart shakes (all structural defects), and pitch pockets, dry rot, dote and worm holes (defects which have an important bearing on the reliability of timber for airplane structures).

## STEELS

Steel plays a vital part in practically all elements of the aircraft structure. While carbon steels first made their appearance in the form of wires and fittings, their use has been extended to include other parts of the structure and alloy steels have entered the field as a result of exhibiting superior strength in tension, compression, shear, and bearing, or desirable qualities in toughness, durability, noncorrosiveness, and the like. That wrought iron and cast iron are not employed is due primarily to their *inferior strength, lack of homogeneity and likelihood of defects.*

## FACTORS INFLUENCING PROPERTIES OF STEEL

The principal factors influencing the properties of steel are: (*a*) Chemical composition; (*b*) heat treatment; and (*c*) mechanical work.

Chemical composition bears a vital relation to the structure of the metal and, hence, greatly affects the physical properties.

## CLASSIFICATION OF STEELS

In the United States, the steel classification of the Society of Automotive Engineers is used in specifications for all high-grade steels employed in automotive and aircraft construction.

A general index system is employed making it possible to use specification numerals on shop drawings and blueprints that are partially descriptive of the quality of material covered by such numbers. The first figure indicates the class to which the steel belongs: Thus 1 indicates a carbon steel, 2 a nickel steel, 3 a nickel-chromium steel, etc. In the case of the alloy steels, the second figure generally indicates the approximate percentage of the predominant alloying element. Usually the last two figures indicate the average carbon content in *points* or hundredths of 1.0 percent. The basic numerals for the various qualities of steels specified are:

| | |
|---|---|
| Carbon steels | 1 |
| Nickel steels | 2 |
| Molybdenum steels | 4 |
| Chromium steels | 5 |
| Chromium vanadium steels | 6 |
| Tungsten steels | 7 |
| Silicon-manganese steels | 9 |

The use of this classification is indicated by the following examples:

### *Example No. 1 (1025 steel)*

First figure 1, carbon steel.
Second figure, 0, no alloy.
Last two figures, 25, carbon range (0.20, 0.30 percent).

### *Example No. 2 (2330 steel)*

First figure, 2, nickel steel.
Second figure, 3, about 3 percent nickel.
Last two figures, 30, carbon range (0.25, 0.35 percent)

### *Example No. 3 (71660 steel)*

First figure, 7, tungsten steel.
Next two figures, 16, tungsten (about 16 percent).
Last two figures, 60, carbon range (0.55, 0.7 percent).

## CARBON STEELS

Carbon steels contain five chemical elements in addition to iron: (*a*) Carbon; (*b*) manganese; (*c*) silicon; (*d*) sulphur; and (*e*) phosphorus.

Carbon combines readily with iron but during the refining process the carbon of pig iron, which may be over 4 percent, is oxidized, necessitating recarburization of the steel to the amount desired by the addition of carbonaceous material. The amount of carbon added depends upon the properties desired in the finished product. *Low carbon steels*, i. e., those which have less than 0.25 percent of carbon, are readily weldable, incapable of being hardened other than by case hardening, and, in general, are similar to iron, being tough and ductile though more homogeneous and hence more reliable. Steels with 0.25 percent to 0.5 percent carbon are termed *mild or medium carbon steels.* They are not as easily welded as low carbon steels but can be hardened to some extent and exhibit greater strength at the expense of ductility. *The high carbon steel*s, i. e., those having 0.5 percent or more of carbon, exhibit increased strength and hardness with increase in carbon content, but at the sacrifice of ductility and weldability.

## ALLOY STEELS

An alloy steel may be defined as a steel that owes its distinctive properties to some element or elements other than carbon. Ternary steels, or three-part alloy steels, are those whose properties are chiefly dependent upon the presence of one element other than carbon and iron. Quaternary steels contain two influential elements other than iron and carbon.

Carbon steels invariably contain small percentages of silicon, manganese, sulphur, and phosphorus, and it has been found that the presence of small quantities of silicon is a distinct advantage, and the same applies to manganese. Both of these elements are usually kept below 1 percent in carbon steels.

When other elements, such as nickel, chromium, molybdenum, vanadium, tungsten and titanium are introduced, even in small amounts, the properties of the steels formed are affected in a marked manner; similarly when either the manganese or silicon content is noticeably increased, the properties of the steel are altered. These steels are usually termed alloy steels and they possess peculiar strength and fatigue-resisting qualities, which render some of them very useful for aircraft work. Superiority in strength-weight ratio over mild steels has been the principal cause for their adoption. Alloy steels are more expensive than carbon steels, more difficult to work, and require, as a rule, considerably more care in the heat treatment which is necessary for the development of their special properties. Without this they are very little better than carbon steel.

The useful *nickel* steels contain between 3 and 5 percent of this element. Such additions increase the ultimate strength appreciably, with only a slight decrease in ductility. One of the greatest advantages is a high yield point (see page 5), which is often increased as much as 50 percent. Another advantage of nickel steels is their ability to resist shocks and repeated stresses, in which they are far superior to carbon steels. Nickel steel parts should only be used after heat treatment. Heat treatment is vital to the procurement of the desired physical properties of chrome, chrome-molybdenum and chrome-nickel steels. With the proper heat treatment these steels combine intense hardness with high strength and yield point. They are also well able to withstand sudden and repeated shocks. Chromium is also one of the principal elements in corrosion resisting steels.

*Molybdenum* is added to steel in amounts varying from 0.2 to 1.0 percent. In these percentages, either alone or combined with chromium, nickel, or both, the physical qualities of steel are greatly improved. Molybdenum increases the temperature at which steel may be successfully hardened and facilitates welding.

*Vanadium* in amounts ranging from 0.15 to 0.25 percent, develops remarkable properties in the steel to which it is added. The ultimate strength and yield point are both increased. The latter is raised as much as 50 percent with no accompanying loss of ductility. Vanadium steels also show exceptional resistance to impact, vibration, and reversal of stress. They are always in heat-treated condition when fabricated. The best combination of physical properties results from the addition of about 1.0 percent chromium and 0.15 to 0.25 percent vanadium to a steel containing from 0.3 to 0.6 percent carbon.

Vanadium is added to high-speed steel in amounts up to 2.0 percent. It apparently acts as an intensifier to the tungsten and chromium since tool steels containing vanadium have superior cutting ability to those in which it is absent. Vanadium and chrome-vanadium steels are uniformly fine-grained when compared with other steels of the same composition and treatment. It is probable that the fine-grained structure is responsible, in a large measure, for the quality possessed by these steels.

*Tungsten,* when present in steels in amounts ranging from 10 to 20 percent confers the property of great hardness at high temperatures. This property, which is known as red hardness, is valuable for tool steels subject to operating temperatures in the neighborhood of 800° F. All tungsten steels are used in the heat-treated condition.

*Titanium* is decidedly beneficial when included (not less than 0.2 percent) in the standard 18Cr-8Ni type of corrosion-resisting (stainless) steel, and when utilized in combination with a low carbon content, i. e., not over 0.07 percent, it facilitates welding and is productive of a stabilized material.

Corrosion-resisting steels cannot be forge welded, but can be welded by the gas or electric method if proper precautions are taken. Welding rods of the same composition as the material being welded should always be used in order that corrosion will not be stimulated by dissimilarity of metals. Gas welding is tedious, slow, and involves intense local heating. Mechanical spot welders give satisfactory and speedy results. Riveting gives a good joint but the process is necessarily slow.

## CHROME MOLYBDENUM STEELS

Practically all aircraft fuselages are made of either welded chrome molybdenum steel tubing or riveted aluminum alloy. In cases where mild steel tubing (1025) is used, replacement of damaged tubes by chrome molybdenum (4130) is satisfactory. Chrome molybdenum sheet steel likewise is being widely used to replace carbon steel. For the sake of uniformity in kinds of material to be carried in stock, use of chrome molybdenum steel for even minor parts, such as brackets and clips, is desirable.

The welding technique of complicated sheet-metal fittings of chrome-molybdenum steel requires special attention, as compared with that of mild carbon steel, to prevent burning or overheating in the weld or cracking near the weld. With very little extra care, however, it is possible to obtain a weld much superior to any that can be made from mild carbon steel from the standpoints of toughness and ability to resist impact loads. Repeated tests of ordinary production welds indicate that the joint develops a greater strength than the original member in the annealed region, just outside of the weld. IT IS IN THIS RESPECT THAT THE CHROME-MOLYBDENUM STEEL WITH ITS HIGHER STRENGTH IN THE ANNEALED CONDITION DEMONSTRATES ITS SUPERIORITY OVER MILD CARBON STEEL.

Machinability after heat treatment, where physical properties are high, is also one of the outstanding characteristics of chrome-molybdenum steel. For machining purposes, chrome-molybdenum steel should be obtained in the annealed condition and, as far as possible, be heat-treated after machining if high strength properties are required, as in landing-gear parts. With annealed stock the difference between the alloy steel and mild carbon steel in such operations as milling, turning, and drilling is scarcely noticeable.

The use of punching dies on annealed chrome-molybdenum steel sheet or the cutting of it in a shear or nibbler is satisfactory, except that considerably higher pressure is required than with the mild carbon steel due to the greater shear resistance of the material. For heavier gages of stock, the thickness of which is beyond the capacity of the ordinary shear, or for material in the "as-rolled" condition, cutting with the oxyacetylene torch is practicable.

Nickel steel (SAE 2330) has many of the desirable strength characteristics of chrome-molybdenum steel but, due to the unsatisfactory welding and brazing characteristics of nickel steel, its use is limited to small machined parts such as bolts, shackles, and the like.

## CASE-HARDENING OF STEEL

Case-hardening of steel is preceded by the carbonizing of the surface to so change the composition that on hardening the exterior, resistance to wear and abrasion is produced, while, at the same time, an interior or core is retained which is tough and strong, to resist shock and stress reversals. Owing to the cost of the process it is only justified on parts subject to shocks and wear such as gears, pinions, wrist pins, splines, etc.

Carbon in the form of charcoal is the usual carburizing compound. Where only a superficial case is desired, cyanide is employed. Low carbon steels are principally employed, with carbon percentages ranging from 0.10 to 0.18 percent giving the best case and toughest core. Alloy steels, low in carbon, are equally susceptible to case-hardening. Nickel increases the strength and toughness of the core while chromium produces a very hard case but one difficult to machine. Average treatment consists of carburizing for 8 hours at 870° to 930°.

In case-hardening with charcoal the parts are surrounded with the carburizing compound in a special metal box having a tight-fitting cover. The box and contents are placed in a furnace and heated to the carburizing temperature and there held for the necessary time. Thereafter the box is removed from the furnace and cooled. The parts are then extracted and heat-treated.

The part is heated to 1,550° to 1,600° F., and quenched in oil. This gives a fine-grained and ductile core. To harden the case the part is reheated to about 1,400° F. and quenched in oil or water. Hardening strains are then removed by drawing at 250° to 400° F.

Cyanide hardening gives a very hard case but one of depth seldom exceeding one sixty-fourth inch. The process consists of immersing the part in a bath of molten cyanide held at 850° to 870° C. From 10 to 20 minutes is sufficient time in which to obtain the desired case. The process is dangerous as both the cyanide and the gases evolved are poisonous. Consequently, the pots should be completely enclosed and forced draft employed to remove the fumes.

## ALUMINUM

In aircraft construction, commercially pure aluminum is used principally for nonstructural parts, such as cowlings, wings, root fairings, wheel "pants," and many other parts which have to be "bumped out" to shape. It is also used in electric wiring, connections, lamps, reflectors, and radios as a plating for its alloys in "Alclad" and light castings. A very important use is as minute flakes, as a pigment for paints, enamels, dopes, used in finished structural members, also for welded gasoline and oil tanks and as a sheet or strip foil for protecting fabric covered structural members from the action of dope.

### ALUMINUM ALLOYS

A consideration of the strength properties of aluminum immediately shows its inadequacy for structural members where strength is a requisite. However, the alloying of aluminum with copper, zinc, magnesium, iron, and nickel has produced results giving aluminum alloys a prominent place among materials for aircraft construction. By aluminum alloy is meant the metal resulting from addition to nearly pure aluminum of one or more of the elements listed above. In general, such addition of alloying constituents produces an increase in strength with a decrease in ductility. Few of the alloys contain less than 85 percent of aluminum and practically all of these have specific gravities below 3. These are the differentiating qualities of aluminum alloys from alloys in which aluminum is an alloying element as, for instance, the aluminum bronzes, where the aluminum content is of the order of 10 percent and the specific gravities are more than double those of aluminum alloys.

Aluminum alloys fall into two classes—wrought and casting. The wrought alloys are those which are designed to be used approximately in the form in which they are received. In this class are foil, sheet, bars, rods, wire, tubing, rivets, nails, bolts, nuts, screws, structural shapes, moldings, and various extrusions.

The casting alloys are those which are to be molded for such parts as cylinder heads and engine parts, and special fittings where high tensile strength is not essential. The casting may be in sand or metal molds, or in die-casting machines under pressure. The wrought alloys are usually not of the same chemical composition as the casting alloys and are ordinarily more complex as to ingredients.

The wrought alloys of aluminum, on the whole, have relatively small percentages of alloying constituents. The aluminum content is ordinarily over 90 percent with the remainder made up of such elements as copper, manganese, magnesium, silicon, iron, and nickel. The ingots for rolling, forging, drawing, and extruding are initially cast. Subsequently, the material is finished in sheet, bar, tube, or other structural shape. These shapes are obtainable from the manufacturer in normal, annealed, or heat-treated condition. It is of vital importance to the construction and integrity of the airplane structure that the condition of the material as received be known accurately.

*Duralumin* was the name originally given to an aluminum alloy patented in Germany about 45 years ago. The alloying elements, copper and magnesium, in small percentages, produced greatly improved physical properties in the metal after heat treatment. For many years the word "duralumin" (often abbreviated to "dural)", was used in referring to aluminum alloys containing the material mentioned above. However, the producers of most of the aluminum used in this country do not acknowledge the name "duralumin" because the term is too general. There are a number of the *strong* aluminum alloys each containing slightly different alloying elements or the same elements in different quantities. The characteristics and physical properties of these alloys vary considerably. Hence no one word is adequate to designate all of them. The manufacturers usually distinguish between approximately pure aluminum and the alloys mentioned above by referring to the latter as the *heat-treatable* alloys.

These alloys may be distinguished from approximately pure aluminum by the fact that they are somewhat darker in color and usually stiffer, regardless of their heat treatment. A simple test is to pour a solution of lye on a sample piece. Unless the piece is Alclad (to be discussed later), the alloy will turn black due to the chemical reaction between the lye and the copper.

The outstanding feature of the heat-treatable alloys is that when they are properly heated and quenched they acquire remarkable strength and stiffness but not until they have been aged—in most cases for 4 days.

These alloys when so treated, although maintaining about the same weight as aluminum, have physical properties which are far more suitable for aircraft construction.

Because of this age-hardening, rivets made of aluminum alloy must be kept in an ice box after they are annealed and until they are used. If this were not done the rivet would be apt to crack when upset.

The following table gives the percentage of alloying elements added to the pure aluminum to produce the various alloys:

| Alloy | Copper | Silicon | Manganese | Magnesium |
|---|---|---|---|---|
| 2S | | | | |
| 3S | | | 1. 25 | |
| 17S | 4. 00 | | 0. 50 | 0. 50 |
| 24S | 4. 20 | | . 50 | 1. 50 |
| 51S | | 1. 00 | | . 60 |

These materials commonly have been used for several years in aircraft construction but will give way to new alloys as soon as better ones are found.

*Corrosion of aluminum alloy.*—The use of aluminum alloy was originally recommended because of its strength and hardness. Its relative resistance to corrosion was presumed or considered high, because of experiences with the pure metal. After considerable use, its susceptibility to surface corrosion and corrosion around the grain boundaries (known as *intercrystalline corrosion*) was discovered. Proper care must be taken to protect the surfaces by a suitable protective material.

This corrosion of aluminum alloy is one factor impeding the wholesale employment of the metal in aircraft work, where weight saving is of such vital importance.

Corrosion of aluminum alloy is first noticed as a dirty white powder deposit, not unlike dust, which blotches the surface of the metal. This blotching is exaggerated as deterioration increases until the metal breaks up in a scaly mass similar to disintegrated zinc (such as the cell of a used dry battery).

The most serious type of corrosion, *intergranular penetration*, or as it is oftener termed, *intercrystalline corrosion*, is particularly difficult to counteract. Its presence cannot be detected readily without the use of a microscope but it manifests itself by accelerated embrittlement of the material, followed by a loss of strength. This corrosion constitutes a break-down of the material at the crystal boundaries, probably the magnesium-silicon constituent $Mg_2Si$, the magnesium particularly being susceptible to corrosion.

Corrosion studies show that, with a few possible exceptions, the corrosion resistance of pure aluminum, which is very high, will be lowered by the addition of alloying elements.

Magnesium is very deleterious, and when this element together with copper is added in sufficient quantities to give maximum strength and hardness, the corrosion resistance is considerably lowered.

In general, hard working of the alloy causes acceleration of corrosion as compared with the annealed material and that moderately rolled or worked. Torch welds in aluminum alloy are particularly susceptible to corrosion due to either lack of homogeneity of the structure or to the fluxes employed. Scratches and other abrasions cause localized corrosion due to the discontinuities afforded serving as recesses for moisture collection.

When an aluminum alloy is exposed to the air, a thin, transparent film of aluminum oxide forms on the surface. Aside from the formation of this film, ordinary atmospheres, relatively free from moisture and contaminating gases, have little or no effect. High humidity conditions, including fog, rain, etc., cause a slow deterioration. Salt atmosphere, on the other hand, produces a relatively rapid dissociation, which salt water contact augments greatly. Fuels such as gasoline, alcohol, etc., attack aluminum alloy slightly if any water is present in the fuel. Fuel dopes with an acid base must be avoided where tanks and lines are made of this material.

Aluminum is a strong electropositive metal and it can be expected that aluminum alloys will corrode rapidly when placed in contact with other metals in the presence of an electrolyte. Excessive corrosion results from contact between aluminum alloy and copper and other similar metals. The former disintegrates completely in a relatively short time, leaving the latter practically unaffected. Deterioration is not as marked with contact between steel and aluminum alloy. However, the two metals should be used only when an insulating strip of fabric impregnated with marine glue or bituminous paint is placed between them. Many instances have shown this electropositive action to have taken place when the metals were separated ⅜ inch; an extreme instance was 2½ inches.

*Uses of aluminum alloy.*—Aluminum alloy, designated by the Aluminum Co. of America as 17S alloy, is finding use in all phases of aircraft construction where a wrought material may be employed. The more important of these uses are summarized below:

1. In sheet forms for:
   (*a*) Bottoms, decks, deep frames, and bulkheads of floats and hulls.
   (*b*) Webs of wing beams and ribs.
   (*c*) Coverings for fuselages, nacelles, and surfaces.
   (*d*) Tanks.
2. In rolled or drawn shapes such as angles, channels, ties, tubes, and extruded sections, for:
   (*a*) Fuselage framework, including longerons.
   (*b*) Interplane and landing-gear struts.
   (*c*) Wing beams and ribs.
   (*d*) Beams and ribs of control surface.
   (*e*) Stiffeners.
   (*f*) Frames, keelsons, chines, etc., of float and hull construction.
   (*g*) Structural members of catapult launching cars.
3. In forged and machine-finished form for:
   (*a*) Propellers both with fixed, controllable, and detachable blades.
   (*b*) Fittings in all parts of the plane structure.
   (*c*) Rivets, machine screws, etc.
4. In stamped or cut form for:
   (*a*) Brackets.
   (*b*) Gussets.
   (*c*) Fittings.
   (*d*) Clips.

## ALCLAD

Taking advantage of the superior corrosion resistance of aluminum of high purity, a process has been developed for manufacturing sheets having a core of aluminum alloy and surface layers of pure aluminum which are integral with the core. This product is obtained by pouring molten aluminum alloy into molds lined with sheets of pure aluminum, after which the billets are rolled, as usual, into sheets. The thickness of each surface layer is 5½ percent of the total thickness of the sheet and is very uniform. The product, after rolling, is heat-treated for from 10 to 15 minutes, during which time the alloy and pure aluminum covering go into solid solution, with diffusion of the former into the latter. This product is marketed as *Alclad 17S or 24S.*

For comparatively thin, highly-stressed sections such as wing ribs and tubular struts used in aircraft, such alloys are preferable materials. For heavier sections, such as engine crankcases, where superficial surface corrosion would be of little consequence even if it should occur, other aluminum alloys are regularly used with entire satisfaction. The use of Alclad for fuselage and wing covering has proved satisfactory.

Tensile test specimens of Alclad exposed for more than 18 months to a standard salt spray test have shown no loss in either tensile strength or elongation. The pure aluminum surface protects the alloy both where it covers the latter and where sheared edges and scratches through the surface layers expose it to electrolytic action.

Ordinary "duralumin" rivets, when used with Alclad sheet, receive a very considerable amount of corrosion protection from contact with the pure aluminum surface. When Alclad is used in seaplane construction, it is advisable to give the sheet the same surface protection that is given to the ordinary aluminum alloy. While service tests have shown that this is not essential, it is considered desirable to add the insurance of satisfactory performance under adverse conditions. For the less exacting service of landplanes, Alclad sheet is in use without the protection of paint coating and is showing satisfactory results.

The susceptibility of the strong aluminum alloys to corrosion along the grain boundaries is well known. Up to the present time no method has been devised which gives better protective results than the anodic oxidation of the surface prior to the application of paint. This process consists of making the alloy the anode in a solution of 3 percent chromic acid under proper conditions of voltage, temperature, and time.

As a simple shop test to distinguish between duralumin and Alclad, make a scratch on the material in question by using a sharp corner of a piece of duralumin sheet. Since duralumin is harder than pure aluminum, the Alclad sheet will show a deeper scratch for the same effort. The difference of the feel and depth of the scratch which is produced on a flat surface of duralumin and on a flat surface of Alclad will leave no question as to which of the materials is Alclad.

## TABLE I

This table lists and shows the strength of the most commonly used aluminum and aluminum alloys:

| Alloy and temper | Tensile strength (pounds per square inch) | Approximate tensile strength after torch welded | Alloy and temper | Tensile strength (pounds per square inch) | Approximate tensile strength after torch welded |
|---|---|---|---|---|---|
| 2S–O | 13, 000 | | Alclad 17ST | 55, 000 | |
| 2S–½H | 17, 000 | | Alclad 17SRT | 57, 000 | |
| 2S–H | [1] 24, 000 | [1] 13, 500 | 24S–O | 26, 000 | |
| 3S–O | 16, 000 | | 24S–T | 65, 000 | |
| 3S–½H | 21, 000 | | 24S–RT | 68, 000 | |
| 3S–H | [1] 29, 000 | [1] 17, 500 | Alclad 24ST | 60, 000 | |
| 17S–O | 26, 000 | | Alclad 24SRT | 68, 000 | |
| 17S–T | [1] 58, 000 | [1] 40, 000 | 51S–W | [1] 35, 000 | [1] 24, 000 |
| 17S–RT | 61, 000 | | 51S–T | 48, 000 | |

[1] Applies to 0.032 gage.

The most popular form of approximately pure aluminum is known as 2S. This is supplied in sheet, plate, wire, rod, bar, extruded shapes, tubing and rivets. 3S which contains 1.25 percent manganese, is supplied in the same shapes (more resistant to salt water corrosion and considerably cheaper than alloys); 17S and 24S are supplied in these forms and also rolled shapes and forgings; 51S comes in the same forms as 2S, 24S, and Alclad.

The letter *T* following a designation number means that the material has been heat treated. The letter *O* indicates the dead soft or annealed condition. *RT* means that it has been cold worked (rolled or drawn) after heat treatment, and has been *strain-hardened* to a slightly higher tensile strength. The ductility is slightly impaired by this process. Some alloys attain their full strength by *aging* at a temperature considerably higher than room temperature immediately following heat treatment. If this aging is not done, the lower strength resulting is called *W* temper. The letter *H* is used in referring to those alloys which do not respond to heat treatment but which harden under cold working, and denotes the degree of hardness. For example ½ *H* means half-hard and *H* means fully hard. It is necessary to know these in carrying out shop processes as well as to know the various specification numbers for these materials, without which proper use cannot be accomplished.

## CASTING ALLOYS OF ALUMINUM

Commercially pure aluminum does not have sufficient strength or hardness for the production of satisfactory castings for aircraft use. The addition of other elements such as copper, zinc, magnesium, silicon, iron, nickel, manganese, chromium, tin, etc., is necessary to minimize difficulties in the foundry, produce the required mechanical properties, and secure the desirable attributes of soundness, machineability and resistance to corrosion. Copper, nickel, and manganese are used to give alloys of moderate strength at elevated temperatures.

There are many combinations of casting alloys, which are principally used in powerplant construction. Their tensile strength ranges from 19,000 pounds per square inch to 30,000 pounds per square inch. However, a few castings are used in construction of fittings where it is easier to make form molds or die castings than to form by some other process. Castings are also used where the tensile strength required is low.

## THE WROUGHT ALLOYS

The wrought alloys will prove a vital factor in the development of the airplane structure, just as the casting alloys have been indispensable to powerplant development.

For example, use of castings and forgings of aluminum alloy has been made for rocker boxes and covers, impellers, intake manifolds, bearing caps, magneto housings, and gears, castings for oil and fuel pumps, carburetors, superchargers, etc. Aileron horns, control stick sockets, etc., are frequently forged, while the variety of shapes of extruded aluminum alloy apply excellently to structural use.

The field of application embodies practically all parts of the airplane, provided acceptable alloys are developed.

## HEAT TREATMENT OF ALUMINUM ALLOYS

The heat treatment of aluminum alloys, such as respond to treatment, differs considerably from the heat treatment of steel.

The temperature is much lower and there is usually no drawing or reheating procedure.

The aluminum alloys are usually heated in a bath of sodium nitrate so as to secure a perfectly uniform distribution of temperature, although they may be heated in air circulated so as to secure uniformity in heating.

The bath itself has no connection with the *solution treatment,* as this expression applies to the action which takes place in the metal, regardless of whether the heat is supplied in a bath or in air.

The solution heat treatment consists of heating the metal to a high temperature to put as much as possible of the alloying material into a solid solution and then quenching in cold water to retain this condition. If effect, the alloying material has been *dissolved* in the aluminum. After quenching the alloy does not immediately possess the strength it will ultimately acquire, but in most cases requires about 4 days, although it reaches approximately 90 percent of its maximum the first day.

This is the aging process, and occurs spontaneously at room temperatures in alloys such as 17S. Others, such as 51S, require an artificial aging at a temperature of about 300° F. for 18 hours. This is known as the *precipitation heat treatment,* and if melted leaves the metal in the condition of temper designated by *W.*

The heat treatment temperature for 17S is 930°–950° F., and is held from 5 to 30 minutes, depending upon the thickness of material. After immediately quenching and aging for 4 days, the designation then is 17ST. The temperature for 24S is 910°–930° F., the rest of the procedure is the same as for 17S except the minimum time is 30 minutes. Its designation is then 24ST. For 51S the temperature is 960°–980° F., and the material is quenched in cold water. If used without further treatment, it is designated as 51SW. If aged for 18 hours at 315°–325° F., it becomes 51ST.

*No time* should be lost in quenching the alloys when coming from the bath or furnace, as a delay of 15 seconds may impair both the strength and resistance to corrosion.

When aluminum or its alloys are worked, bumped, rolled, formed, or drawn, they become strain-hardened. This hardening may be removed by *annealing.*

Annealing is accomplished by heating the metal to 640°–670° F. and slow cooling to 450° F. after which the rate of cooling is unimportant. This removes the effects of cold working and most of the effects of any previous heat treatments. The fully annealed or dead soft O condition is brought about for heat-treated alloys by heating to 750°–800° F. for 2 hours and then cooling in a furnace to a temperature of 500° F. The cooling rate should not be faster than 50° F. per hour down to this point. Below that limit the cooling rate is unimportant.

If the alloying material is heated above 985° F. its physical properties will be permanently impaired.

## COPPER AND ITS ALLOYS

The principal use of copper in aircraft construction is for powerplant appurtenances, where the high electrical and heat conductivities more than balance the weight consideration. The other factors dictating employment are: Resistance to corrosion, fair strength, flexibility, and ease of fabrication.

The more important uses to which copper may be put in aircraft work are summarized as follows:

(*a*) In short form or strips for:
1. Gas and oil tanks.
2. Flashing on floats and hulls (wooden).
3. Bending where ribbon is used.
4. Shims and washers.
5. Propeller tipping (wooden).

(*b*) In tube form for:
1. Gas and oil lines.
2. Leads of airspeed meters, etc.
3. Water lines.
4. Radiator cores.
5. Heater coils.

(*c*) In wire form for:
1. Ignition wiring.
2. Radio wiring.
3. Lighting wires.
4. Safety wiring.
5. Tacks (wooden floats and hulls).
6. Bonding.

Copper forms a very useful series of alloys with metals such as zinc, tin, iron, aluminum, and others, to which definite names have been given, as follows:

*Brasses.*—Alloys of copper and zinc, sometimes with small amount of lead and tin.

*Bronzes.*—Alloys of copper and tin, sometimes with small amounts of other metals.

*Aluminum bronzes.*—Alloys of copper and aluminum.

*Phosphor bronzes.*—Alloys of copper, tin, and small amounts of phosphorus.

*Manganese bronzes.*—Alloys of ordinary bronzes with ferromanganese.

*German silver.*—Alloys of copper and nickel, sometimes with tin or zinc.

*Monel metal.*—Alloys of copper, nickel, and iron.

*Bearing metal.*—Alloys of copper, tin, lead, zinc, iron, and antimony (the first three metals alone, with or without any of the last three).

*Silver solder.*—Alloys of copper, silver, and zinc.

*Cupro nickel or Constantin.*—Alloys of copper and nickel.

The principal classes of copper alloys are termed brasses and bronzes. They are called either *True* or *Complex*, depending on whether one or more alloying elements are present in solid solution with the copper. The true brasses are solid solutions of zinc in copper whereas the true bronzes are solid solutions of tin in copper. The principal alloying elements of complex brasses are aluminum, iron, lead, magnesium, manganese, nickel, silicon, and tin. Those of the special bronzes are zinc, lead, and phosphorus.

*True brasses.*—The true brasses constitute those copper-zinc alloys in which the copper content is greater than 49 percent. The valuable alloys contain from 60 to 90 percent copper and 10 to 40 percent zinc. The brasses are stronger and more ductile than either of their constituents. They may be cast or wrought.

*70–30 brass,* also known as "cartridge brass," owing to one of its important uses, is employed in aircraft construction both in wrought and cast forms. As sheet it is used for parts requiring spinning as well as for rubbing strips, propeller tipping, and the like. In cast form it is used as fittings for tanks, radiators, heaters, etc. This brass has good resistance to corrosion and excellent cold-working qualities.

*Complex brasses.*—The complex brasses are alloys of copper and zinc with one or more other metals, principally aluminum, iron, lead, manganese, magnesium, phosphorus, and tin.

*Manganese bronze.*—Manganese bronze is really a complex brass containing very small percentages of tin, iron, and manganese.

Owing to its high strength, the facility with which it may be forged or rolled, and its resistance to corrosion, manganese bronze is used in catapults, landing gears, tail skid fittings, caps, and brackets.

*Naval brass* is used for similar purposes and is much like manganese bronze in composition but lacks manganese and has only a trace of iron and sometimes aluminum.

The wrought material is used for turnbuckles owing to excellent resistance to corrosion, ready machineability, and high tensile strength. Clinch nails are made from the wire.

*Tobin bronze* is very similar to Naval brass in composition. Its distinctive properties are due to rolling and annealing. It may be regarded as having the strength and ductility of structural steel besides being noncorrosive. It is readily hot-worked and machined, and is used for turnbuckles, fittings, etc.

*True bronzes.*—The true bronzes, or copper-tin alloys, may be regarded as hardened copper, the tin acting as a hardener with very little effect on strength. The true bronzes, in consequence, have no useful field in aircraft work but certain of the complex bronzes are in general use.

*Complex bronzes.*—The principal constituents added to the copper-tin alloys are zinc, lead, and phosphorus. Zinc increases the fluidity and soundness of the material besides lowering the cost. Lead likewise lowers the cost of the alloys. It improves the machineability and in bearings aids plasticity. Phosphorus is a deoxidizer and hardener.

*Phosphor bronze* is usually considered as any copper-tin alloy to which phosphorus has been added as a deoxidizer. The phosphorus is usually added in the form of phosphor-tin or phosphor-copper. Phosphor-bronze containing less than 9 percent of tin and up to 0.25 percent phosphorus can be forged and resists corrosion. It is used for drawing into rod and wire. Phosphor-bronzes for casting purposes usually contain from 8 to 14 percent tin and from 9.25 to 1.0 percent phosphorus.

*Aluminum bronzes.*—The effect of aluminum in small percentages upon copper is considerable, that is, up to 10 percent both the yield point and tensile strength progressively increase. The aluminum bronzes are useful for their high tensile properties, their shock resistance, their corrosion resistance and their workability and would find considerable use in aircraft construction but for a comparatively low strength weight ratio as compared with alloy steels.

*Monel metal.*—Monel metal, essentially an alloy of copper and nickel, has long been in use for carburetor needle valves, sleeves, etc. Its corrosion resistance is extremely good. Nuts, bolts, control parts, and fittings are readily manufactured of monel metal and recently experimental seaplane floats have been built of it.

| | *Per cent* |
|---|---|
| Nickel | 69 |
| Copper | 28 |
| Iron | 2 |
| Manganese, silicon, and carbon ( combined) | 1 |

Monel metal combines strength and stiffness with inherent resistance to the forms of corrosion found in aircraft parts. The assurance that pitting, intercrystalline corrosion, or other deterioration will not take place is particularly desirable in airplane construction. The excellent salt water resistance of monel metal is well known. However, in electrolytes like salt water, the use of two metals unlike in electrochemical behavior in galvanic contact is very dangerous in stimulating corrosion. Corrosion of light metals and of steel is greatly accelerated when in such contact with monel metal.

*Babbitt.*—This alloy is essentially one of copper, tin, and antimony. Babbitt is used as a bearing metal against a backing of phosphor-bronze, steel, or duralumin.

## FABRICS

The weight and strength of fabrics are standardized to meet the minimum requirements of Government regulations. The weight of airplane fabric is limited to 4.5 ounces per square yard. The strength depends upon the number and type of thread used.

The modern wing fabrics use a 60-strand, 2-ply yarn, both in the lengthwise threads, called warp, and in the cross threads, called fill, or filling. The minimum thread count is 80 threads in each direction. The strength of the fabric should be at least 80 pounds per inch in both directions.

Long staple Egyptian or Sea Island cotton fiber is ordinarily used, a staple length of not less than 1½ inches being specified. The fibers are thoroughly cleaned and freed of waste after which they are combed to uniform structure.

This results in a smooth cloth that is free from any fuzziness or nap. This is an important asset to producing a smooth finish. No starch or sizing is used in the weaving because the absorbent qualities must be maintained.

Mercerizing consists of steeping the yarns in a solution of alkali (caustic soda or caustic potash) at a cool temperature, then putting it under tension, and lastly rinsing it. The process entails a shrinkage in bulk of about one-fourth and produces a luster somewhat like silk. This treatment both strengthens and softens the yarn.

It also reduces the moisture content of the fabric. As excessive moisture is not desirable, airplane fabric should not be stored in a damp place.

*Fabric tape*, or wing tape, as it is popularly called, is a narrow fabric tape that is doped to the covering for the purpose of covering the stitches and as a reinforcement. It is made from the same material as the airplane fabric and must meet the same standard. The widths run from 1¼ to 3¾ inches depending on the size needed for each type of work.

The edges of wing tape are usually pinked to prevent the threads from unraveling. Pinked edges also simplify the job of getting these edges to stick tightly to the fabric.

*Reinforcing tape* is a strong, heavy tape used for reinforcing and binding. It is supplied in 36- to 50-yard rolls of widths ranging from ¼ to 1¼ inches. Probably the greatest use for this tape is as a reinforcement under rib lacing. This heavy tape prevents the rib stitching from tearing through the fabric. Reinforcing tape is also used for rib cross bracing and in binding parts in place. The A–N specification tape is exceptionally strong, having heavy warp threads while the commercial tape, herring-bone weave, is a lighter tape. Both have their specific purposes in aircraft construction.

The *threads* and *cords* used are generally of a linen thread in a left twist, 9-strand unbleached cord. It is generally made of Irish flax and is not waxed. The linen cord used for rib lacing is usually of about 50 pounds tensile strength. It is also supplied in Nos. 16, 20, 24, 28, ranging in strength from 160 pounds for No. 16 to 300 pounds for No. 28. These heavier cords are used for fuselage lacing and side openings in the fuselage.

The left twist is necessary, as many sewing machines have a tendency to untwist a right-hand-twisted thread. Machine sewing thread is used to make machine-sewed seams in fabric.

Hand sewing threads should be carefully selected and graded so that the correct type is used on trailing edges, control surfaces, etc., generally of an approximate 9 pounds tensile strength.

All rib stitching and hand sewing thread should be coated with beeswax before using, as the beeswax preserves the thread and also prevents its fraying. Waxing also assists in hand sewing since the thread has less tendency to twist while sewing. Beeswax is applied by pulling the thread over a cake of beeswax several times.

## MISCELLANEOUS MATERIALS

*Asbestos* is the most important of the silicates of magnesium. It is soft, fibrous, and a nonconductor of heat and electricity. It is used in sheet form between plates for fire walls and heat-insulating districts and is indispensable between light copper shells, as in gaskets.

*Cadmium* has but recently come into general use, though the electroplating process with cadmium was patented in England in 1849. This metal is found mainly as a carbonate or sulfide in ores of zinc. The amount of cadmium in these ores is rather low; about 1 part in 400.

The softness of cadmium is such that it will mark paper. Due to its malleability it is superior to zinc, nickel, or chromium as a corrosion-resistant coating, since it is more resistant to knocks and blows. A firmly adherent coating of soft and tough material will outlast a brittle and feebly tenacious deposit. Because of its remarkable *throwing power*, cadmium will enter almost any recess when deposited electrolytically. Chromium and nickel are poor in this respect.

*Magnesium and beryllium* are used as alloying materials, both being much lighter than aluminum.

*Celluloid.*—Celluloid is a mixture of nitrocellulose and camphor. When these two materials are mixed together they form a plastic mass which can be molded into any desired shape. In aircraft construction it is primarily used in sheet form for windshields and inspection windows.

The latest type enclosed cockpit covers and windshields are being made out of cellulose base material, very similar to celluloid but manufactured quite differently. Its resistance to atmospheric and climatic conditions is much greater.

*Cork* is obtained from the bark of certain trees, principally the cork oak. It is light-colored, porous and has a specific gravity of only 0.24. Owing to the strong watertight walls of the cells the material is very elastic and when compressed exerts an increasingly great resistance. It is used for heat insulation, fuel valve seats, floats for certain gasoline gages, gaskets, and vibration insulators.

*Felt.*—Felt is a compressed wool or wool and cotton mixture of varying quality dependent on the quality of the constituents. For hard felt, wool must be used alone, as cotton does not harden in the felting or filling process. In aircraft work felt is used for lining tank straps and in other places to prevent chafing as well as for installation of instruments against vibration. Either felt or flannel impregnated with soybean oil can be used as a base for water and oil stops.

*Glass.*—Nonshatterable glass, which is the type principally employed in connection with aircraft, is produced under several patented processes, a common type consisting of two pieces of glass with a sheet of celluloid between, adhesion being effected by the use of a strong transparent cement, under great pressure. When a composite sheet of this type is struck a heavy blow it cracks in a large number of places radiating from the point of impact.

Windshields, windows, instrument faces, and goggles all utilize glass which is usually of nonshatterable construction.

*Leather.*—Leather is obtained principally from the hides and skins of domestic animals. Prior to tanning of the hides, the hair, flesh, and useless parts are removed, following by washing and trimming. The tanning process is undertaken to stop decomposition, to give the hides greater strength, toughness, and pliability, and to make them impervious to water. The processes are the tanbark treatment, treatment with different oils or tallow, and the chrome or chemical process.

Leather of various grades finds use in a variety of articles essential to flight, the more important of which are listed below: Cushions, pads on cockpit cowlings, chafing strips and pads, lacings, headrest coverings, float bumpers, strainers (Chamois), gauntlets, moccasins and shoes, puttees, helmets, jackets, winter flying suits, and straps and safety belts.

*Solder.*—Two types of solder are in common use, i. e., soft solders and hard solders. The former are essentially alloys of tin and lead and the latter alloys of copper and silver or zinc. *Brazing*, in which the spelter of copper and zinc is employed, is often termed "hard soldering" when done with a torch.

Aluminum solder is of a tin base with the addition of zinc, aluminum and other metals, the chief function of which is to produce a semifluid mixture within the range of soldering temperature. It must contain at least 10 percent zinc and 7 percent aluminum and not more than 1 percent of either copper or antimony.

*Soft solders* are employed to effect metal joints where high strength is not required.

To secure clean surfaces free from oxide a suitable flux must be used which will either dissolve the oxide as fast as it forms, or will reduce it again to metal. The usual fluxes are zinc chloride, ammonium chloride, rosin, and stearin.

## EFFECTS OF MECHANICAL WORK

Aside from casting, which has been discussed, some form of mechanical work offers an alternative means of shaping metals. Mechanical treatment may take the form of hand and drop forging, rolling, pressing, drawing, extruding, bending, and similar processes. Such work may be accomplished either with the metal at room temperature or heated. Hot working produces an increase in the strength of the material owing to the breaking up of the large, coarse, crystalline masses brought about by slow cooling. Furthermore, the pressure applied serves to close up gas cavities and blowholes and to elongate solid nonmetallic inclusions into threads of fibers.

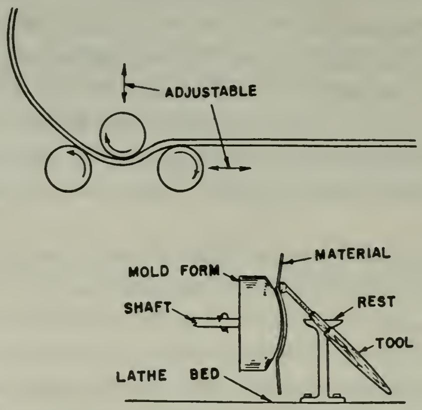

Figure 12.—Rolling and spinning operations.

Coldworking likewise insures greater strength and further produces a high surface finish and section accurate in size. The increase in strength, elastic limit, and hardness of the cold worked material is accompanied by an increase in brittleness. Annealing at a temperature just below the critical range, however, produces a very desirable structure, eliminating excessive brittleness.

*Rolling.*—As a shaping or forming operation, *rolling* is employed both in the fabrication of shapes and in the bending of sheets to the desired curvature. The process is essentially the same regardless of the material employed.

The process of *hot rolling* in the fabrication of shapes from ingots is divided into three main divisions: Heating, roughing, and finishing. The first includes preparing the ingots for the roughing and reheating the partly rolled sections for the finishing mills. Roughing includes breaking the ingot down into the sizes and shapes necessary for the various finishing mills. Finishing is what the name implies, i. e., rolling the finished section.

In aircraft construction, forming rolls are extensively used with sheet metal both for flattening and producing curvature. It should be noted that sections up to one-eighth inch in thickness are termed sheets, while above that they are designated as plates.

Rolls likewise often are employed in converting sheet strips to desired sections, such as channels. These rolls are not the cylinders used for bending and flattening but moulded plates keyed to axles so that they will effect the desired curvature of the strips. Beading and swaging are forms of this type of rolling.

Sheets are beaded where allowance is to be made for expansion, as in tank work. The copper, aluminum or other sheet is passed through small hand rolls along the line it is desired to produce the bead. This amounts to producing a rounded groove, as shown in figure 13.

*Forging.*—While rolling is a less expensive process for obtaining relatively simple sections in large quantities, *forging* is better adapted to more complicated sections. Forged sections are of higher quality than are rolled ones, primarily on account of superior pressure control in fabrication.

The process of *hand forging* consists of shaping the material heated to a plastic or semimolten state by means of special tools such as hammers and sets, by hand. In aircraft work, particularly with aluminum alloy, it is used to a great extent on work in the experimental stage of development and consequently requiring only a small number of the same parts. The various curvatures and shapes are obtained by beating sheet stock over wooden forms. Cowling and large sheets requiring undevelopable curvatures are likewise pounded to the desired shape on wooden forms.

*Drop forging* consists in making the semimolten, or hot and plastic material flow under pressure or repeated hammer blows into the cavities formed in one or a pair of strong metal molds or dies. One of the dies is attached to the hammer; the other to the anvil. The results are similar to those obtained by casting but greater homogeneity, strength, and accuracy of shape are obtained. Owing to the labor and expense incurred in making the dies, the process does not pay unless large quantities are being turned out.

*Curvatures in sheet stock may be effected by a type of forging termed bumping.*—The sheet is placed on a rounded anvil of a bumping hammer and a rounded head pounds the sheet. It is moved between blows. Curvature of the metal in more than one plane is thus accomplished.

*Pressing.*—Pressing is a form of forging in which a steady application of pressure is utilized rather than an instantaneous one, as in hammering. It has the advantage in that work affects the whole cross section of the piece instead of just the surface. While for very heavy work hydraulic forging presses are employed, aircraft parts as a rule require only such pressure as can be readily delivered by mechanical presses. Stamped fittings are made on punch presses, which are small mechanical presses. The large presses are used for pressing aluminum alloy sheet to the form required for webs of wing ribs and bulkheads of floats and hulls. Here a single die with sheet rubber may be used in lieu of a second matched die, or male and female dies may be employed. Streamline tubing is readily converted from the round section under the press, using wooden or metal pressing forms in two halves. These allow for the spring back of the metal.

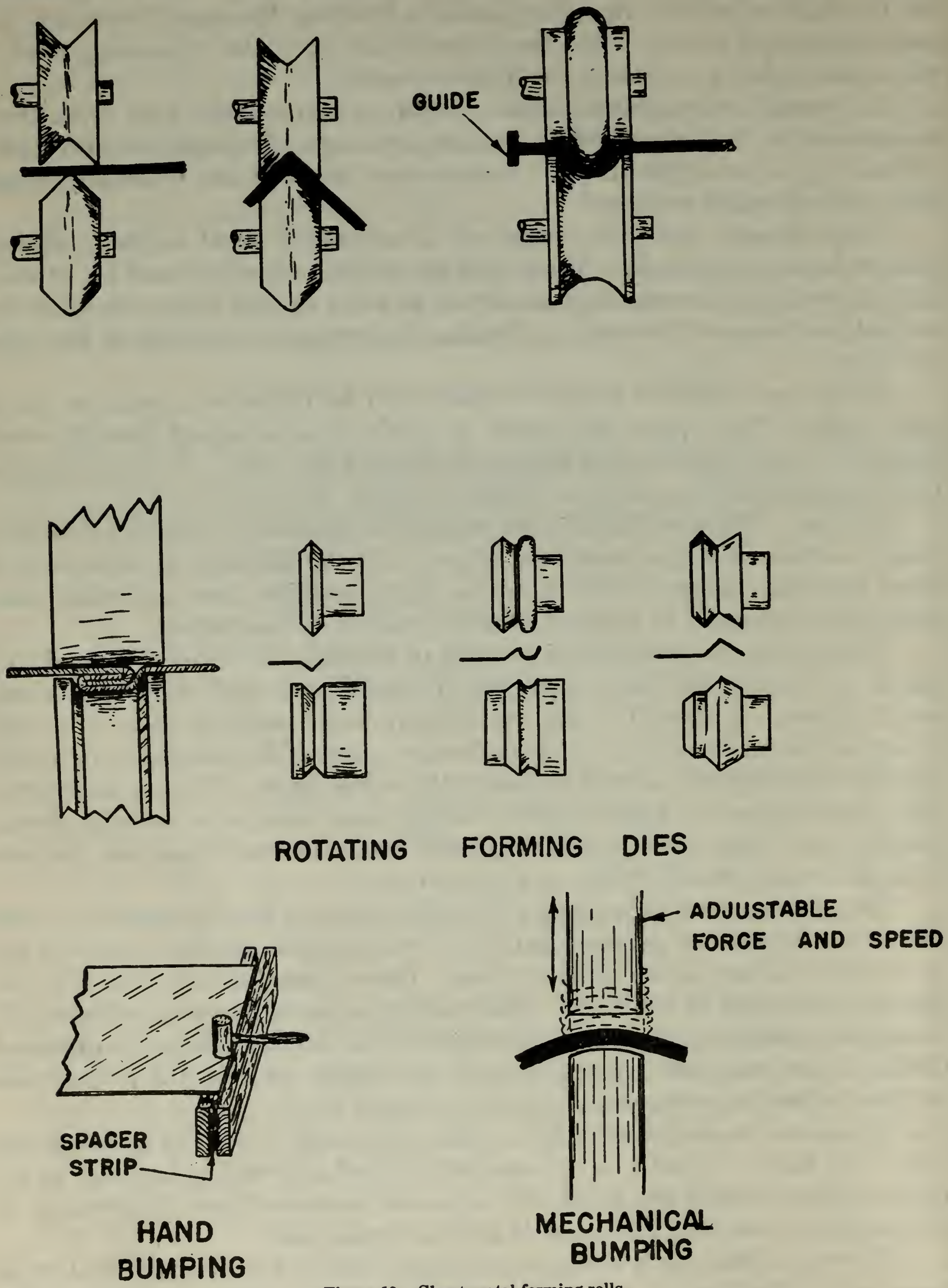

Figure 13.—Sheet metal forming rolls.

*Bending.*—Shallow bends in sheet stock are accomplished under rolls, bumping hammers, and presses or by hammering over wooden forms. Sharp bends or flanges are made with bending brakes, either hand or power operated.

The method of bending a pipe or tube varies with the metal, its diameter, and the curvature required.

In bending a steel tube a fairly fine grain sand is poured slowly into the tube, the lower end of which is either pinched or plugged to contain the filler. To insure good packing the tube should be tapped continuously with light blows. When the tube is filled, the upper end is plugged and the tube heated by a yellow or reducing flame. The heat should be applied gradually to the position which will be on the outside of the bend until a bright red color is evidenced. The inside of the tube should be kept as cool as possible to resist the compression occurring during bending. Best results are obtained by heating short sections, making slight bends, and repeating until the desired curvature is obtained. The tube may be bent by hand or by a bulldozer to somewhat greater extent than actually required. In cooling this slight excess will be drawn out by contraction. The finished-bent tube should be allowed to cool to blackness in air and then may be cooled in a water bath and the plugs and sand removed.

Aluminum alloy tubing to be bent should be annealed, filled with melted rosin, and when the rosin has congealed, bent to the desired form. The rosin is then melted out by gently heating the end of the tube with a blowtorch, taking care not to overheat the metal nor melt the rosin in the middle before the ends are clear, as this would burst the tube. Finally the tube is heat-treated. The minimum radius for bending is about three to six times the diameter of the tube, the radius of bend being specified for each material.

Copper and brass tubing are handled in the same manner as aluminum alloy—rosin, pitch, or lead being used for loading after annealing. Sand or water may be used in emergency, but if a plug gives way, as may easily occur, the tube will buckle and be spoiled. For shallow curves sanding and, in some cases, heating of the tube are unnecessary. For sharp curves both are ordinarily essential to prevent buckling or change of section.

*Spinning* (see fig. 12) is a particular bending process for sheet material, practicable with nearly all metals. It is susceptible only to contours symmetrical about an axis as cup, cone, bell, and spherical shapes. A hardwood form is attached to the chuck of a lathe and a flat sheet centered at the protruding axis. A blunt tool is then forced against the sheet as the lathe revolves, causing the metal to be driven back against the form. A polished steel tool is employed with aluminum alloy, whereas a wooden tool may be used on aluminum.

*Drawing* is primarily employed in the manufacture of seamless tubing and wire but may be effectually employed in the fabrication of thin sheet sections of fairly intricate contour, which are extensively used in wing beam flanges and other strength members of the airplane. The work is cold-drawn or pulled through dies to finally produce the proper cross section.

*Machining.*—While machine tools are employed in various of the foregoing processes, *machining* has the principal significance of referring to the finishing of castings and forgings to exact form and dimensions.

The *lathe* is employed to effect: (*a*) Cylindrical or spiral surfaces; (*b*) any variety of surfaces of revolution; and (*c*) cuts perpendicular to the axis of revolution. The *drill* is employed to cut cylindrical holes. The *planer* is used to cut plane surfaces or straight grooves. The *shaper* is virtually a planer for planing small work. *Milling machines* are used for both plain and intricate cutting of great variety.

Several other machines of lesser importance find a place in machining operations, but to a limited extent.

The cutting speed of tools is determined by the heat generated in cutting. When the tool and the work cannot conduct this heat away fast enough, the tool point becomes heated and is itself ground away. This condition of heating is avoided in many tools like milling cutters, metal saws and rotary planer cutters, where each tooth does not cut continuously. For continuous cutting by one tool point, as in the lathe, the high speed steels are far superior to carbon steel for removing a large quantity of metal but carbon steel tools are better for the lighter finishing cuts. Some high speed steels will cut satisfactorily with the tool point at a red heat.

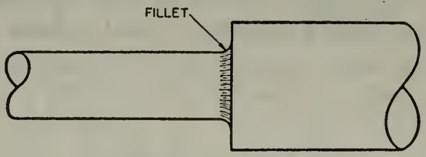

**Figure 14.—Shafting fillet.**

Oil or soapy water, applied to a cutting tool, assists in keeping down the temperature while the latter gives a smooth bright surface to the finishing cut of iron or steel.

To safeguard the strength of metal, a fillet (see fig. 14) should always be left at the enclosed angle formed by the junction of two surfaces in different planes, as where a rod diameter abruptly changes.

### *Questions*

1. Why is wood still used in aircraft construction?
2. Why have some airplanes been made entirely of metal?
3. List the principal woods used in aircraft construction and indicate where they are commonly used.
4. What does the strength of wood depend upon?
5. List the defects which disqualify wood for aircraft construction.
6. Why are wrought iron and cast iron seldom found in aircraft?
7. What are the principal factors involved in the properties of steel?
8. Explain the steel symbol 1025.
9. What chemical element constitutes the major part of carbon steel?
10. Distinguish between low carbon, medium carbon, and high carbon steel as to their composition and physical properties.
11. What is the difference in composition of an alloy steel and carbon steel?
12. What advantages are sought when an alloy metal is mixed with iron?

13. What must be done to alloy steel to bring out its best qualities?
14. What is the principal steel used for fuselage tubing?
15. Why is it preferred to the 1025 steel?
16. Why is 2330 steel seldom used for fuselage structure?
17. What are the advantages of case hardening?
18. How is it accomplished?
19. Where is pure aluminum sheet most frequently used?
20. Why is it preferred to aluminum alloy for these parts?
21. In what forms are wrought aluminum alloys available?
22. Where are casting alloys of aluminum used?
23. Why is aluminum alloy preferred to steel for much of the airplane structure?
24. What is the most important alloying material used in heat-treatable aluminum alloys?
25. What is one unique characteristic of aluminum alloys with respect to heat treatment?
26. What does age-hardening have to do with aluminum-alloy rivets?
27. Describe the appearance of corrosion of aluminum alloy.
28. How is intercrystalline corrosion detected?
29. Why must aluminum-alloy joints be riveted?
30. Discuss electrolysis in aluminum-alloy structures.
31. What is the principal advantage in the use of alclad?
32. How thick is the surface layer on 0.040-sheet alclad?
33. Would you expect corrosion in an alclad sheet along the edge of the sheet? Why?
34. How would you distinguish between alclad and aluminum alloy.
35. List the alloys and tempers of aluminum and aluminum alloy and explain the meaning of the symbols used.
36. What is meant by solution heat treatment?
37. How does heat treatment of aluminum alloy compare with that of steel?
38. Why must aluminum and its alloys be annealed when they are worked?

# CHAPTER III.—STANDARDIZATION

It is presumed that the student understands the need for some system of standards in an industrial age such as ours. The airplane has come into the age and has required that new or additional specifications be prepared for the designation of material and parts used in its construction.

Specifications prepared by the American Society of Mechanical Engineers (A. S. M. E.), the Society of Automotive Engineers (S. A. E.), and others are used as far as they go. The modern airplane requires additional specifications and the Army and Navy, who have great influence over airplane design, prepare and certify the AN System for items acceptable to both services.

There are also specifications under the title of Air Corps, Naval Aircraft Factory, Federal, and others, which a designer of aircraft should have available.

## "AN" SPECIFICATIONS

*AN specifications* are used primarily for specifying the kind, size, and quality of small aircraft parts. These specifications were drawn up through the cooperative action of the Army and Navy, but apply equally well to commercial aviation.

In this system, the specification number is divided into two groups; the first group designates the kind of aircraft part, and the second group designates the size. Included in the part designation is the heat-treat, material, and finish which is acceptable. As an example, AN515B designates roundhead, coarse thread, brass machine screw. AN515B–6–10 designates the roundhead, coarse-thread, brass machine screw, No. 6 diameter, with a length of five-eighths inch. This system of specifications may appear very complicated until the reader has opportunity to make a specific study of it.

The following table gives some of the specification numbers used for common parts. It is incomplete because of space limitation and it does not show how the size of the part is specified. If the complete list is desired by the student he may refer to airplane-part catalogs or to the Army drafting-room manual.[1]

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[1] Available from the Army only to airplane manufacturers.

## *Partial Index to Group Specifications*

**Bolts.**

| | |
|---|---|
| Bolts—hexagonal head aircraft, drilled for cotter | AN3–AN16, inclusive |
| Bolts—clevis | AN23–AN36, inclusive |
| Bolts—eye for pin | AN42–AN49, inclusive |
| Bolts—aircraft, drilled head | AN73–AN81, inclusive |

**Cable fittings.**

| | |
|---|---|
| Thimble—wire cable | AN100 |
| Shackle—cable | AN115 |
| Turnbuckle assembly—cable eye and fork | AN130 |
| Turnbuckle assembly—cable eye and pin eye | AN135 |
| Turnbuckle assembly—cable eyes | AN140 |
| Barrel—turnbuckle | AN155 |
| Fork—turnbuckle | AN160 |
| Eye—turnbuckle, for pin | AN165 |
| Eye—turnbuckle cable | AN170 |
| Pulley—control | AN210 |

**Fabric accessories.**

| | |
|---|---|
| Fastener—cowl—post type | AN226 |
| Grommets—plain and spur—with washers | AN230 |
| Eyelets—lacing | AN240 |

**Keys.**

| | |
|---|---|
| Key—Woodruff | AN280 |

**Nails.**

| | |
|---|---|
| Nail—flathead—cement coated | AN301 |
| Pin—escutcheon | AN302 |

**Nuts.**

| | |
|---|---|
| Nut—aircraft, castle | AN310 |
| Nut—aircraft, plain | AN315 |
| Nut—aircraft, check | AN316 |
| Nut—aircraft, shear | AN320 |
| Nut—machine screw hexagonal (coarse thread) | AN340 |
| Nut—machine screw hexagonal (fine thread) | AN345 |
| Nut—wing | AN350 |
| Nut—slotted, engine | AN355 |
| Nut—plain—engine | AN360 |

**Pins.**

| | |
|---|---|
| Pin—cotter | AN380 |
| Pin—flathead (clevis) | AN392–AN406, inclusive |

**Rivets.**

| | |
|---|---|
| Rivet—countersunk head, iron and copper | AN420 |
| Rivet—countersunk head, aluminum alloy and aluminum | AN425 |
| Rivet—roundhead, aluminum alloy and aluminum | AN430 |
| Rivet—roundhead, iron and copper | AN435 |
| Rivet—flathead, copper and iron | AN441 |
| Rivet—flathead, aluminum alloy and aluminum | AN442 |
| Rivet—tubular | AN450 |
| River—brazier head | AN455 |

**Rod ends.**

| | |
|---|---|
| Clevis—rod end brazing | AN481 |
| Clevis—rod end adjusting | AN486 |

**Screws.**

| | |
|---|---|
| Screw—filled head aircraft drilled (fine thread) heat-treat steel | AN502 |
| Screw—flathead, coarse thread, brass, steel and aluminum alloy | AN505 |
| Screw—flathead, fine thread, brass, steel and aluminum alloy | AN510 |
| Screw—roundhead, coarse thread, brass, steel and aluminum alloy | AN515 |
| Screw—roundhead, fine thread, brass, steel and aluminum alloy | AN520 |
| Screw—sheet metal—flathead | AN531 |
| Screw—sheet metal—roundhead | AN530 |
| Screw—drive—roundhead | AN535 |
| Screw—roundhead, wood, brass and steel | AN545 |
| Screw—flathead, wood, brass and steel | AN550 |

**Tie rods—fittings.**

| | |
|---|---|
| Clevis—tie rod—rigid | AN665 |
| Tie rod—streamline | AN671, AN673, to AN682, inclusive |
| Tie rod—internal | AN701, AN703, to AN708, inclusive |

**Tube fittings.**

| | |
|---|---|
| Clamp—tube | AN740 |
| Cock—drain—screw type | AN771 |
| Nipple—union | AN780 |
| Coupling—union (brazing) | AN785 |
| Elbow—union | AN790 |
| T—union | AN795 |
| Cone—union | AN800 |
| Nut—union | AN805 |

**Washers.**

| | |
|---|---|
| Washer—lock | AN935 |
| Washer—plain | AN960 |
| Washer—flat, for wood | AN970 |

**Wire.**

| | |
|---|---|
| Ring—lock | AN996 |

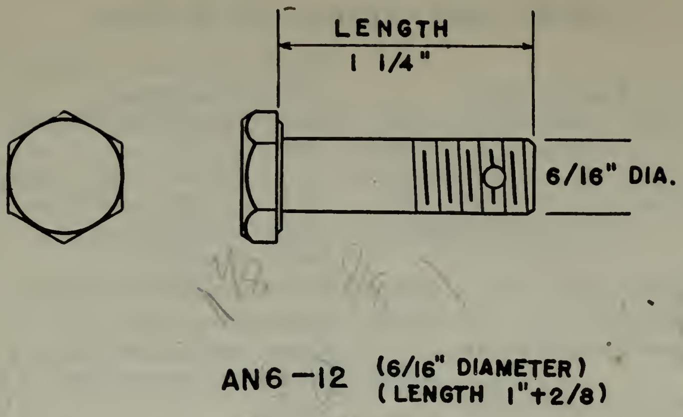


Figure 15.—Aircraft bolt.

### "AN" SPECIFICATIONS FOR SIZE

The following will show how sizes of parts are specified, and the use of these data with the table given previously will make possible proper designation for the referred-to parts.

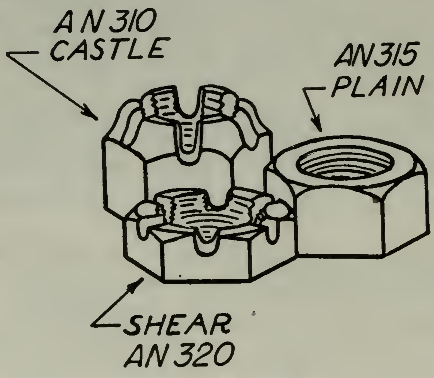


Figure 16.—Aircraft nuts.

As an example, the aircraft bolt AN number designates the diameter in sixteenths of an inch, and the dash number designates the length in eighths of an inch up to an inch. 1 or 2 precedes the number of eighths of an inch if the bolt is longer than 1 inch. For example, AN6–6 is an aircraft bolt 6/16-inch diameter and 6/8-inch length; AN6–16 is a bolt 6/16-inch diameter, but 1 6/8 inches long. The designated length is 1/64 inch longer than the distance from the base of the head to the center of the pinhole.

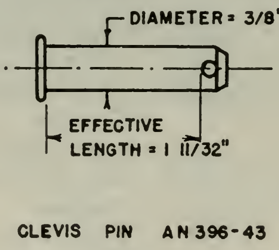
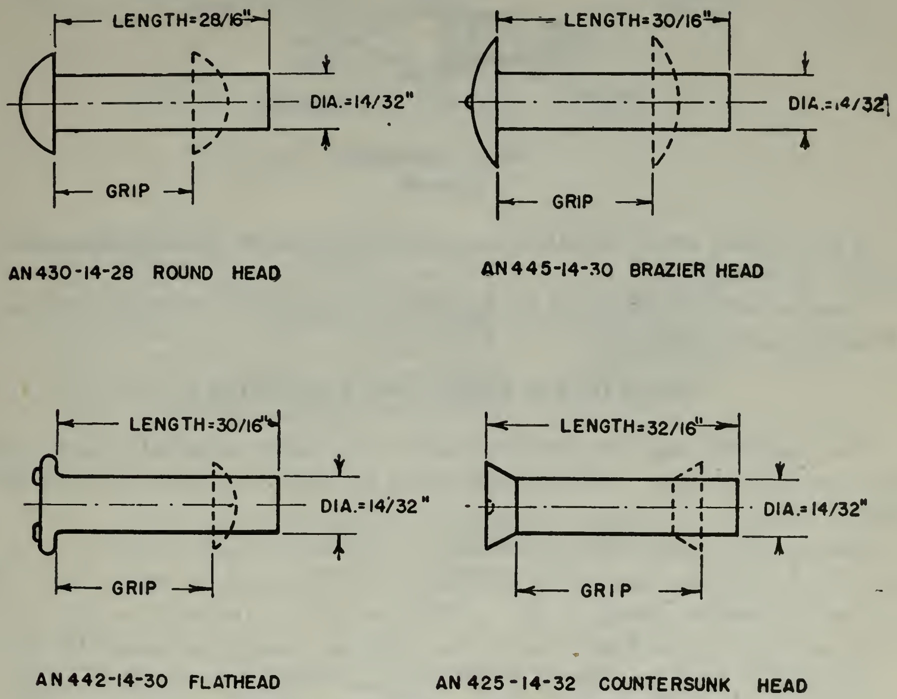


Figure 17.

*Nut Sizes* are designated by a dash number which is the number of sixteenths of an inch diameter. This is true of almost all nuts.

*Machine screw sizes* are specified by two dash numbers. The first is the wire gage diameter up to No. 12 then by sixteenths: Thus 416 means four-sixteenths, 516 means five-sixteenths, etc. Length is specified by the second dash number, which designates the number of sixteenths inch of length. Example—AN515–12–5 (diameter No. 12, length 5/16), AN515–416–5 (diameter, four-sixteenths, length, five-sixteenths).



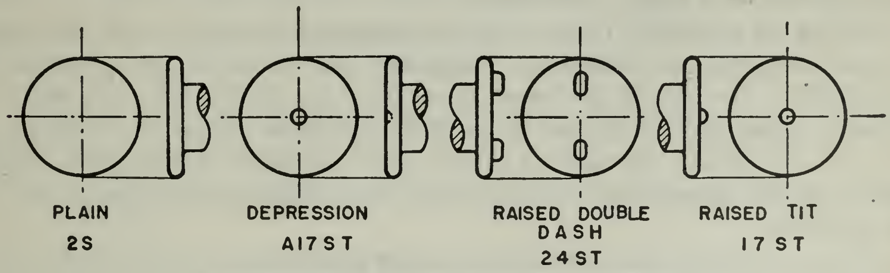
AN430-14-28 ROUND HEAD

AN445-14-30 BRAZIER HEAD

AN442-14-30 FLATHEAD

AN425-14-32 COUNTERSUNK HEAD

Figure 18.—Rivets. Head marking designates material.



PLAIN
2S

DEPRESSION
A17ST

RAISED DOUBLE DASH
24ST

RAISED TIT
17ST

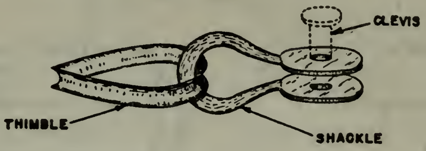
Figure 19.—Material identification marks on rivet heads.

*Cotter pin size* is specified by two dash numbers. The first is the number of thirty-seconds inch diameter, the second is the number of fourths inch length.

*Clevis pin size* is specified so that the last number of the AN group designates the diameter in sixteenths inch and the dash number the number of thirty-secondths inch length. AN393–17 (diameter 3/16, length 17/32).

*Nail sizes* are specified by two dash numbers. The first is the diameter in wire gage number, the second is the length in eighths of an inch.

*Rivet size* is specified by two dash numbers. The first is the thirty-secondths inch of diameter, the second is the number of sixteenths inch of length.



CABLE TERMINAL

Figure 20.

*Washer sizes* are designated by one dash number which is the diameter number of the bolt.

*Thimble size* is designated by a dash number which is the sixteenths inch of diameter of the cable.

## STANDARD AIRCRAFT MATERIALS

The materials used in aircraft consist principally of metal, wood, rubber, fabric, paint, and dope. The specifications of those used commonly are briefly outlined below.

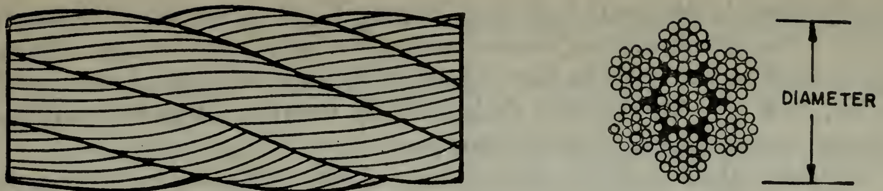
**Metal.**—The material specifications for *metal* include designation of the alloy, the heat-treat, and the condition of the material as well as the shape, size, and protective coating used. The material is ordered by the aircraft factory or repair depot from the vendor who has made or stocked the item.

Steel sheet used in aircraft structures is generally one of three alloys: (1) X–4130 chrome-molybdenum sheet steel used for fittings, braces, etc.; (2) 1025 mild carbon aircraft steel sheet used for fittings, etc.; or (3) 1095 high-carbon hot-rolled spring steel furnished annealed, which can be easily cut then hardened for use.

The other materials in sheet form are specified in a similar way. The size is the same as standard mill size by B. w. g. (Birmingham wire gage) for thickness, standard length, and width.

*Tubing* for aircraft is made of the same material as sheet stock and carries the same material specification. There are two common forms, round and streamlined. The size of the round is specified by outside diameter and wall thickness. The wall thickness is generally in thousandths of an inch, but B. w. g. is also used. Streamline tubing size is specified by giving the outside diameter of the round tube from which the streamline tube was made, and the wall thickness.

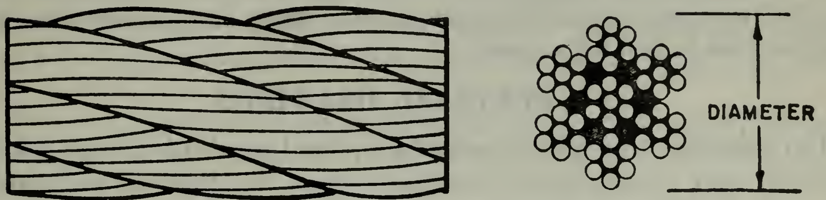
*Cable* used in aircraft is available in either preformed or nonpreformed type. The difference between these is the method of wrapping the wires of which the cable is made. In the preformed type the cable will not fray out when it is cut. Both types are available in three kinds:



EXTRA - FLEXIBLE CONTROL CABLE

7 X 19 CONSTRUCTION

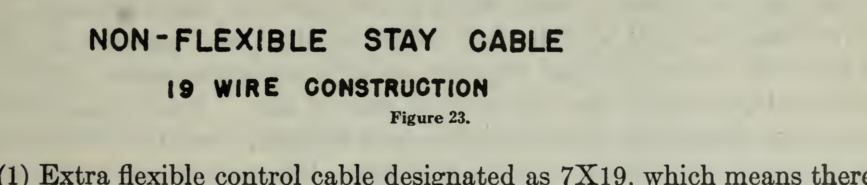
Figure 21.



FLEXIBLE CONTROL CABLE

7 X 7 CONSTRUCTION

Figure 22.



NON-FLEXIBLE STAY CABLE

19 WIRE CONSTRUCTION

Figure 23.

(1) Extra flexible control cable designated as 7X19, which means there are 7 strands with 19 wires per strand.

(2) Flexible control cable, designated as 7X7 consisting of 7 strands with 7 wires per strand.

(3) Nonflexible stay cable designated as 19 wire, which consists of 19 wires in 1 strand, or 7 wire consisting of 7 wires in 1 strand.

The diameter of the cable is given in fractions of an inch, and is the largest outside diameter. Materials used are: (1) High strength steel wire—tinned or galvanized; and (2) stainless steel wire.

**Wood** though not as much used in aircraft at the present time as in the early days still is used often enough to require careful specifications. The wood generally used is designated Aircraft Spruce U. S. Army Specifications No. 82–2–B. The specification of size is in common lumber terminology. Plywood, which is used considerably in some types of planes, carries the Army Specification No. 82–6–C. Thickness is designated by fractions of an inch and length and width of sheets are standard by inches.

**Airplane fabric** used for the covering of some types of airplanes is made from cotton. It is available in several grades: (1) Grade A, (2) super balloon, (3) regular balloon, and (4) light airplane. The manufacturer of an airplane will determine which grade of fabric to use for repair.

**Aircraft dope** comes in three kinds—the clear nitrate, the pigmented nitrate, and the semipigmented dope. The specifications of these dopes may be in accordance with Army-Navy requirements, and by designation of color. In general, the dope used and recommended by the manufacturer of the airplane should be used in making repairs.

## STANDARD DRAWINGS

The drawings used for the manufacture and repair of aircraft are made in accordance with standardized procedure which has been established by the Army and the Navy and augmented by the manufacturer's drafting-room manual. It is impracticable in this text to give much detail concerning these standardized practices, but it is considered desirable that a pilot have some knowledge concerning them since he may be in a position where he is expected to double check the repair or alteration of aircraft which are specified in drawings.

The basic principles of drafting which are commonly used for machine drawings are also the basic principles of airplane drawings. Since the construction of aircraft is very complicated and since most of it is done directly from drawings certain definite procedures have been established so as to reduce the number of drawings required and to definitely specify the material, the finish, and the weight of each part. Standardized parts need not be drawn but are manufactured to specification.

Drawings are made to scale which is designated in the title block. The preferred scales are full, double, four times, one-half, and one-fourth. When parts are small, or are grouped together, enlarged scales are used. If the part is simple and quite large, the reduced scale may be used. Since it is desirable to use drawings as small as convenient, the size of paper should be the minimum which can accommodate the required drawing. Drawings made to scale should be held to an accuracy of one thirty-second of an inch. However, the size of a part should be obtained from the dimensions on the drawing rather than by scaling off the drawing.

Two kinds of drawings are used, the flat sheet and the roll. The flat sheet must fold conveniently to a size 8½ by 11 inches to facilitate filing in the standard letter file. The roll-size drawings may be as large as 36 inches in width and 12 feet long.

The lettering on aircraft drawings must all be upper case (capital) letters and must be arranged so that they can be read from the bottom edge of the drawing. This practice is followed without exception even in the case of dimensions which are vertical.

There are five types of drawings commonly used by aircraft manufacturers. These are:

(1) *Detail drawings.*—This is a drawing of a separate part which will later be assembled to other parts.

(2) *Assembly drawings.*—This drawing shows the assembly of two or more parts into a unit.

(3) *Installation drawing.*—This drawing shows groups of parts or assemblies which comprise a major unit of an airplane structure such as the fuselage installation drawing which shows the location of all fixed points in the fuselage.

(4) *Lay-out drawing.*—This is a general drawing of a section of the airplane in which the lay-out of various parts is arranged and from which detail drawings of these parts can be made to fit the completed structure.

(5) *Rework drawings.*—When it is desirable to rework a part so that it may be used, this drawing is prepared to show how such rework operations can be carried out.

Standard aircraft drawings are made to show the part as viewed from the left-hand side of an airplane which is pointed to the left. In cases where a part is symmetrical about the center line only the left-hand side is drawn, and an indication is made that the other half is symmetrical. In the case where a left-hand part is matched by a right-hand part of similar shape, only the left-hand part is drawn and a notation is made that the right-hand drawing is opposite.

Each drawing will contain a title block which consists of a large blocked-off space generally at the bottom of the page which gives information concerning the following items:

(1) The part name.
(2) The drawing number.
(3) The model number of the plane.
(4) The number of parts required.
(5) The material used including size, kind, and specifications.
(6) Scale and tolerances.
(7) The heat-treat.
(8) Finish required.
(9) Protective coating required.
(10) Weight.

In addition to the title block a drawing will contain a table of changes which is filled from the bottom toward the top as change in the drawing is required.

The drawing itself will include instructions for the machining and manufacture of the part so that the completed drawing will represent accurately the completed part. Wherever possible, AN numbers are used and standard specifications for materials and finishes are included.

Before altering or repairing aircraft, it is necessary that the drawings be very carefully studied and that the work be performed in such a way that the completed job will meet the manufacturer's recommendations.

Figure 24 shows the drawing of an aircraft part. This is a detail drawing and gives sufficient information to a workman so that he should be able to construct the part represented.

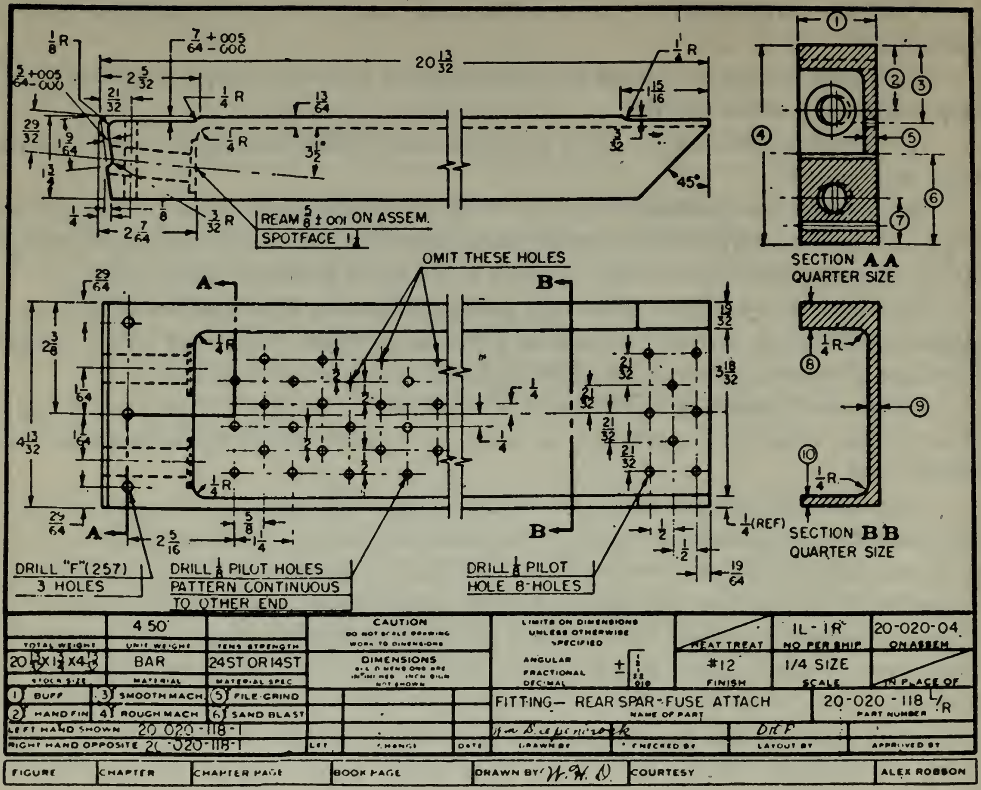


Figure 24.—Typical detail drawing.

## RECOMMENDED FINISHES

*Standard parts.*—Threads on adjustable parts, such as tie rods and turnbuckles, should be greased before assembly. Standard parts, such as bolts and nuts, should be coated prior to assembly with the initial priming coat wherever practicable and painted to match the adjacent surfaces after assembly. The threads on adjustable aluminum alloy parts must be coated with an antiseize compound before assembly. Rivet heads should be cleaned and immediately touched up or sprayed with the initial priming coat after driving. Steel bolts used in highly stressed fittings must not be painted but must be generously coated with rust-preventive compound.

*Acidproof finish.*—Surfaces within at least 12 inches of storage batteries or parts further removed which are subject to acid spillage or spray must be given two coats of acidproof paint in addition to the regular finishes. Two coats of varnish should be applied over the acidproof paint.

*Dope proofing.*—Aluminum foil should be applied over the regular specified finishes to all metal parts which come in contact with fabric. The aluminum foil must be 0.0005 inch thick and must be attached by means of a nonhygroscopic foil adhesive or shellac.

*Control cables.*—Control cables must not be painted but should be coated with either (1) a mixture of white lead and tallow, (2) graphite, or (3) grease.

*Tank supports.*—Tank supports should be painted with at least one coat of primer and two coats of enamel and in addition must be insulated from the tanks by means of pads conforming to the requirements. Pads must be carefully placed in the proper position when the tanks are installed. Due precautions must be taken to secure the pads to the supports to prevent their shifting position.

*Wrapping.*—The wrapping of structural members to facilitate fastening of fabric covering tends to promote corrosion and must be eliminated wherever practicable. When wrapping is deemed necessary, the inspector's approval shall be obtained. Lower longerons and lower cross members must not be wrapped with fabric.

*Faying surfaces.*—Nonwatertight faying surfaces should be painted with two coats of the initial specified protective coating or one coat of primer, and one coat of enamel. Each coat must be allowed to dry before assembly. After assembly the exposed surfaces of the parts must be given the specified number of coats, care being taken to paint along the joints.

Watertight faying surfaces must be similarly prepared and, in addition must have a strip of fabric weighing not over 4.5 ounces per square yard impregnated with soybean oil-varnish compound, bituminous paint or marine glue or equivalent, inserted between the contacting surfaces upon assembling the parts. Soybean oil-varnish compound is used as a stop water.

*Copper-bearing alloys.*—Brass, bronze and copper parts, where their use is authorized, need not be painted unless it is necessary because of contact with aluminum alloy or to fit in with the color scheme.

*Tubing.*—Steel tubular members must be sealed to exclude the entrance of moisture by welding. Aluminum alloy tubular members must be left open at the end to permit drainage. Aluminum alloy tubular members must be finished the same on their interior as on their exterior surfaces. The use of steel fittings in conjunction with aluminum alloy tubing is not favored. End fittings used with open tubing must be designed so that they do not form pockets which might collect and retain moisture. After all welding and brazing operations have been completed, the interiors of closed steel members must be protected by a coating of hot raw linseed oil or by a rust-preventive compound. The liquid must be applied by forcing it under pressure, or by immersing the part in a bath. The liquid must be at a temperature of not less than 160° F., when applied, and must be allowed to remain in the member for not less than 2 minutes. The liquid must be forced into each individual tube by drilling small holes close to the end of the members, or may be forced through the complete assembly by drilling interconnecting holes at the strut joints. The presence of the liquid in the tubes must be checked by noting the increase in temperature. If immersed, all parts must be manipulated to insure the absence of air pockets and must remain in the bath until all bubbling has ceased. The members must be thoroughly drained, wiped free from oil, and all holes drilled in the members which are open to the outside must be sealed with cadmium-plated self-tapping screws or equivalent. Solder must not be used to close these holes. When self-tapping screws are used in structural members, care must be exercised to place them in regions of lowest fiber stress and in carefully selected locations to prevent structural weakness and difficulties. The diameter of the hole must bear such relation to the pitch diameter that tightness is attained without stretching, cracking, or splitting the surrounding metal.

*Corrosion prevention.*—Resistance of a material to corrosion is tested in conformity with standard procedures which have been developed. One of these for metals consists of the salt-solution test. In this case, the material is sprayed with a salt solution. If no corrosion appears at the end of 100 hours, the corrosion protection is satisfactory for ordinary service. The resistivity of some coatings tested is salt spray in shown below.

| Material Tested | Hours Resistivity |
|---|---|
| Chromium, over nickel, over steel | 18 |
| Nickel, over steel | 4 |
| Nickel, over copper, on steel | 14 |
| Nickel, over cadmium, on steel | 80 |
| Zinc, over steel | 316 |
| Parkerizing; linseed oil finish, over steel | 141 |
| Chromium, over steel | 3 |
| Cadmium (0.0001 inch thick), over steel | 150 |
| Cadmium (0.0004 inch thick), over steel | 1,000 |
| Cadmium (0.001 inch thick), over steel | 3,000 |

From this table it is apparent that cadmium plating over steel is a superior coating. For parts which do not lend themselves to cadmium plating, and for other materials besides steel, coatings of paints or enamels, or oils and greases are used. The aircraft manufacturer will specify the kind of corrosion prevention which he recommends.

## NECESSITY FOR STANDARDIZED PARTS

Heat treatment for steel, aluminum alloy, and other materials is standardized and must be specified accurately if the desired qualities of the material are to be obtained. It might be added in this connection that manufacturers of aircraft parts have developed systems of quality control which assure the user of their parts that the part is up to standard in every way. When aircraft parts are replaced because of wear or damage, the owner of the plane should make sure that the new parts meet the specifications for the original. Manufacturers of aircraft have selected vendors who best are able to furnish specification parts for their planes. It is therefore urged that the manufacturer's parts list be consulted for these parts.

Manufacturers of aircraft and engines will furnish the owner of a plane with manuals which will assist him in safe operation. It is urged that the student make an effort to borrow copies of these manuals and familiarize himself with the contents. From time to time, manufacturers issue service bulletins and modify operating instructions. These bulletins and notes likewise should be carefully studied and followed. In case of doubt concerning the interpretation of the manufacturer's data, the owner of a plane should write to the manufacturer's representative and obtain a proper interpretation.

### *Questions*

1. What is the meaning of each of the two groups which constitute the AN number for an aircraft part?

2. Give the name and the size of the parts designated by the following AN specification numbers: (*a*) AN3–4, (*b*) AN27–15, (*c*) AN76–10, (*d*) AN3–10, (*e*) AN310–7, (*f*) AN380–2–2, (*g*) AN420–3–7, and (*h*) AN505B–416–10.

3. Give the AN number for the following parts: (*a*) No. 10–32 roundhead, brass, machine screw, ½ inch long, (*b*) ⅛-inch cotter, steel, 5⁄16-inch long, and (*c*) aircraft bolt, steel ½-inch diameter 3-inch length.

4. If cadmium plate could not be used, what other metal might prove suitable for corrosion prevention?

5. Why is it desirable to be cautious concerning the use of questionable materials for aircraft structures?

6. What does 1025 mean as applied to steel?

7. How is the size of streamline tubing specified?

8. What scales are used for aircraft drawings?

9. What are the five types of aircraft drawings and what is the purpose of each?

10. What information is included in the title block?

11. How are the threads on aluminum alloy bolts prevented from seizing?

12. Where should acidproof finishes be used?

13. How are control cables lubricated?

14. How is the inside of a steel tubing protected against corrosion?

15. How is the inside of an aluminum alloy tubing protected against corrosion?

16. Describe the process of finishing the inside of the tubing of a welded steel tube fuselage to prevent corrosion.

# CHAPTER IV.—JOINING, FASTENING, AND SAFETYING

## JOINING PROCESSES

In the preceding chapter, a brief outline of the stock materials and small parts which a manufacturer will use to build an airplane was given. The present chapter will specify how these materials and parts may be joined together.

### WOOD JOINING

Wood used in aircraft construction is joined to other wooden parts primarily by the use of glue, and secondarily, by the use of nails, wood screws, and bolts. The glue used most frequently is casein glue which is derived from milk. This glue is obtained in powdered form and mixed with cold water (50° to 70° F.). The proportion of glue and water is specified by the glue manufacturer and must be followed carefully. The usual amount is one part glue to two parts water by weight. It may be mixed by hand by adding glue powder to water while the mixture is being stirred. Care should be exercised during the mixing to prevent the forming of lumps. The mixture should set for 15 or 20 minutes and then stirred again for 1 to 5 minutes. The glue is then ready to use. This glue should not be stored, but should be discarded 3 to 4 hours after mixing.

Wood members which are to be glued together should have contact surfaces which fit accurately. It is better that the parts be machine worked due to greater accuracy of the machine over hand work. The glue is spread adequately on the joint which is then clamped tightly or nailed so as to spread out the glue in a thin film and expel bubbles of air. Pressures ranging from 125 pounds per square inch for softwood up to 200 pounds per square inch for hardwood are standard. The glue will set in from 2 to 7 hours.

Splices to repair broken wood parts are also joined by the use of glue. A joint with a taper of 10 to 1 is satisfactory for most of these joints, which are called scarf joints. The accompanying illustration (fig. 25) shows a splice used in the repair of a broken wing spar.

### METAL JOINING

The construction of aircraft requires that metal parts be joined together. One of the following processes probably will be used in making this joint: (1) soldering, (2) brazing, (3) welding, (4) riveting, or (5) seaming.

The discussion which follows will give a brief outline of each process and describe typical application.

*Soldering.*—This is the process of joining by which two metals are "glued" together by the use of another metal of lower melting point. The metal commonly used where low strength will be satisfactory is a lead and tin alloy called solder (for higher strength a silver solder is used). The process of soldering consists of tinning the parts to be joined in the vicinity of the joint, and then spreading molten solder on the joint. A flux must be used to cause the solder to adhere to the metals being joined. The heat for this operation may be supplied either by soldering copper heated in a furnace or electrically, or by the flame of a gasoline or alcohol torch. Soft soldering is ordinarily used for radiators, tank work, electrical connections, and similar places.

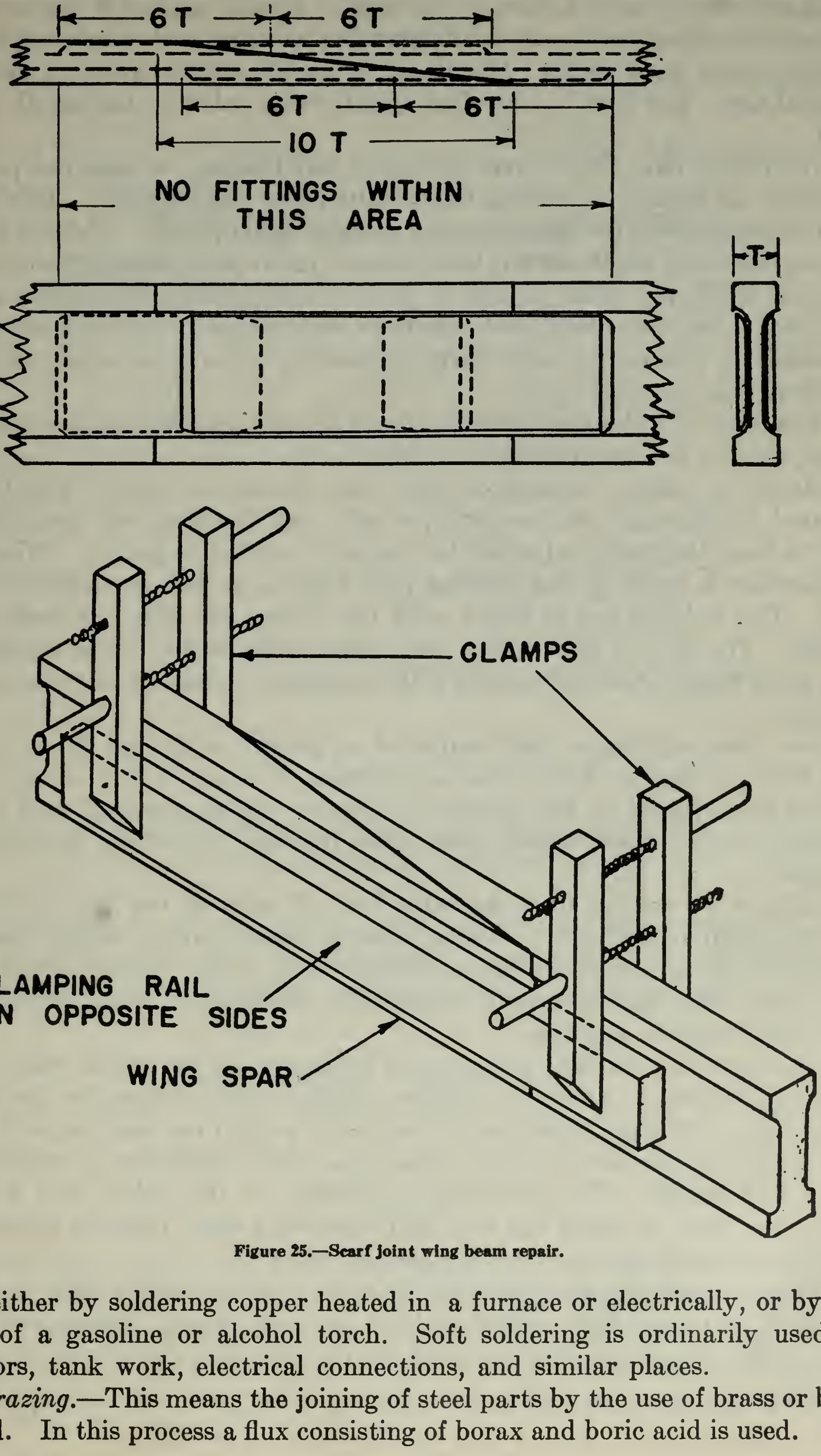


Figure 25.—Scarf joint wing beam repair.

*Brazing.*—This means the joining of steel parts by the use of brass or brazing rod. In this process a flux consisting of borax and boric acid is used. The process consists of heating the parts to be joined, and by the use of flux and brazing rod to tin the joint with brass. After tinning, additional brass is applied by melting the rod into the joint. When the joint is well filled it is cooled and excess flux and brass are removed. Heat is applied in most cases by the use of a welding torch. A welding torch is a device used to mix oxygen and acetylene, and burn them. The flame is ignited at the end of a specially designed tip. The flow is controlled by adjusting valve on the handle of the torch.

*Welding.*—This differs from soldering and brazing because the parts to be joined are heated to melting temperature, and run together. This makes a continuous joint of the same material as the original pieces. Welding may be used on materials which are not heat-treated, or on parts made of heat-treated materials which are small enough to permit heat treatment after the weld is completed. In some cases, particularly in some forms of electrical welding, it is possible to join heat-treated parts by welding without materially changing the strength.

The forms of welding commonly used in aircraft construction are: acetylene or gas, electric arc, and resistance welding.

*Acetylene welding* is used on steel and aluminum joints. The joint is prepared by cleaning and beveling properly and the acetylene torch then is used to heat the metal adjacent to the joint until it is plastic. When this temperature is reached, the welding rod, dripped in flux, is melted into the joint. The welding rod is added until the proper size fillet, or bead, is deposited. The joint is then cooled and made ready for use. The welding rod must be of proper kind and quality if the completed joint is to have the desired strength.

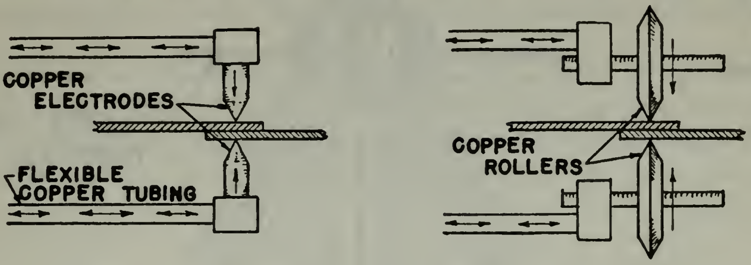
For most welding, a torch adjusted to provide a neutral flame is used. This flame is one in which there is no excess of either oxygen or acetylene. Typical parts joined by this process are engine mounts made of steel tubing, landing gears of steel tubing, steel tube fuselage, aluminum cowling and fairings.

*Electric arc welding* does the same kind of work as the acetylene torch, but has, until recently, been suited best to heavy parts. Either direct or alternating current is used, but in aircraft work, direct current seems to be preferable. The direct current is generally produced in a motor-generator unit, which may be portable.

This unit is connected to the work by heavy copper cables which carry the welding current. One of the cables, either positive or negative, depending on the rod and the job, is securely attached to part of the work or to a bench upon which the job is to be done. The other cable terminates in an electrode holder and handle. The electrode is clamped in the holder and touched against the work to strike the arc, then removed a short distance so that the arc will continue between the electrode and the work.

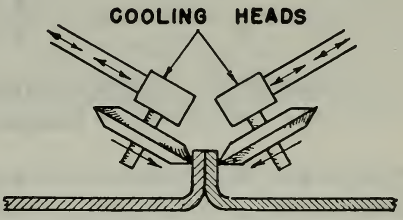
The arc melts the electrode and the work and the joint is made by filling the crack and spreading a fillet or bead over the joint. Proper electrodes and current magnitude must be used to be sure of a good weld of proper strength.

*Resistance welding* is performed by pressing the materials to be joined together between two electrodes through which the current is passed. This method is used when flat surfaces of steel, aluminum, or aluminum alloy sheets are to be joined. It will replace riveting in many jobs. In this instance the electrodes do not join into the weld, but rather conduct current into the sheet at the joint where the weld is required. The current passing through the crack between the sheets causes a high temperature due to resistance, thus melting the metal and running it together. After cooling, the joint is complete. (See fig. 26.)



SPOT

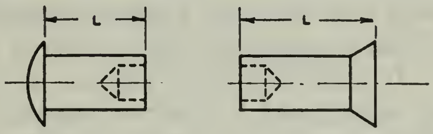
LINE OR SEAM



LINE OR SEAM

Figure 26.—Resistance welding.

Electrodes may be of point or wheel type. The point type works like a sewing machine and makes a small welded spot where used. The wheel type makes a continuous weld as the sheets are rolled between the wheels.

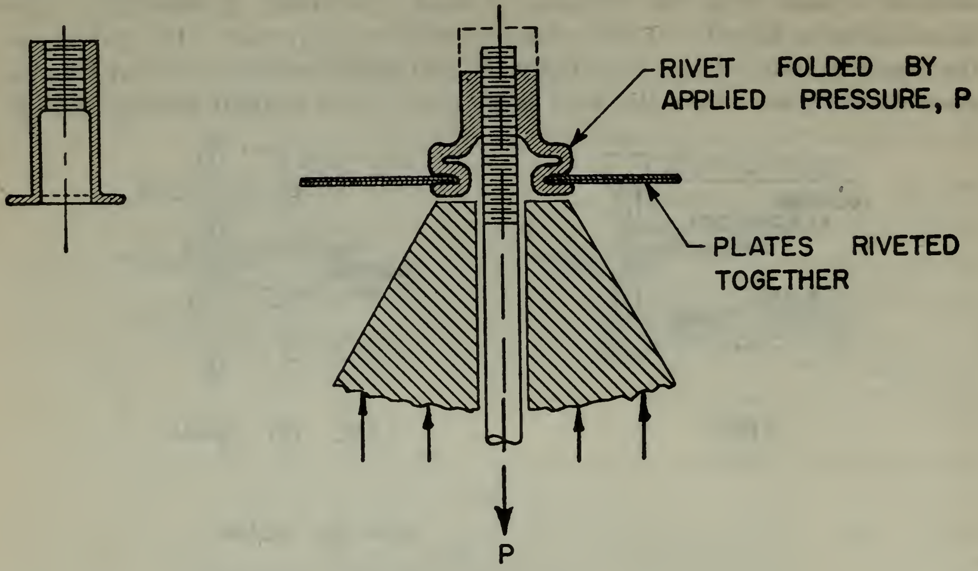


TUBULAR RIVETS

Figure 27A.

*Riveting.*—Some joints cannot be welded so these are generally made by riveting. The rivets are set in holes drilled into both sheets. These holes must be properly spaced and of correct diameter. The rivet is inserted into the hole and upset, or headed, by use of an air hammer, electric hammer, or hand hammer. Rivets used in aircraft come with various heads such as the round head, flat head and button head.

They are available in various materials to match the sheets being joined. Some of these are of a kind of aluminum alloy which must be heat treated prior to using so that the rivet will be soft when upset. These rivets, after heat treatment, are stored in an ice box to retard hardening.



RIVNUTS (BLIND RIVETS)

Figure 27B.

*Hollow rivets* (see fig. 27A) and patented *blind* rivets are used in places where common rivets are not suitable. The *blind* rivets are installed when it is not possible to get a bucking tool on the shank of the rivet due to inaccessibility. These rivets are upset from one side of the sheet. One of these rivets is shown in figure 27B.

*Seaming.*—All stress skin construction uses either riveted or welded joints. There are, however, parts of aircraft which may be joined by the use of *seams or folds*. (See fig. 28.) This practice, which is common in general sheet-metal work, is applicable in aircraft parts such as tanks, baggage compartments, battery boxes. These folds or seams are often soldered if the material is one which can be soldered. It is also necessary that the material used be suitable for cold working to an extent which involves relatively sharp 180° bends. Such materials as aluminum, copper, and monel may be used if they are in the annealed condition.

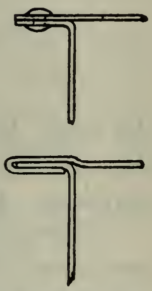


Figure 28.—Folded seams.

## FASTENING

Parts which are intended to be taken apart during the life of an airplane are joined together by the use of fastening devices, the majority of which use screw thread. These parts in general work under either tension or shear loading. Occasionally the part used for shear loading will be of materially different design than that loaded in tension. Representative items will be discussed briefly.

## BOLTS AND NUTS

Aircraft bolts are made of steel or aluminum alloy. The material can be identified as meeting AN specifications for strength and corrosion resistance if a star is found on the head of the steel bolt and two small grooves on the head of the aluminum alloy bolt. These bolts are made in various lengths and diameters. It is important that the bolt length be large enough so that there is no pressure applied against the threads by the structure. (See figs. 15 and 16.)

In other words, the nut and washer should occupy all of the threaded length of the bolt. On the other hand, the bolt should not be so long that more than two washers, one a sixteenth and the other a thirty-second of an inch thick, will be required when the nut is tightened and the cotter-pin hole is at the base of the slot in the nut. No washer should be required under the head of the bolt unless the parts being joined are materially softer than the bolt head, as is the case with wood or aluminum alloy. After the bolt is installed, the nut should be safetied by the installation of a cotter pin.

Whenever possible a bolt should be installed in accordance with the *down, in, back* rule. This rule means that the shank of the bolt should be installed in a downward position, rearward position, or in toward the fuselage.

This direction of assembly aids in preventing the bolt from falling out if the nut should loosen, and also helps the pilot inspect those which are visible from the cockpit. It is desirable to install a bolt so that it is not necessary to turn the head when tightening.

Bolts loaded in tension should have a common nut, either plain or castle. This nut has enough threads in it to transmit the full tension load without risk of stripping. Bolts loaded in shear may use a shear nut, which has few threads and is not intended to carry heavy tension loads.

*Clevis bolts* are designed primarily for shear loading, and are used in place of clevis pins when the greater security afforded by a threaded nut and cotter pin is preferred to the cotter pin alone. They are made of the same material as aircraft bolts and have an X on the head to designate that they meet AN specifications.

*Drilled head aircraft bolts* are used in places where the bolt is inserted in a threaded hole so that cotter pins and nuts are not needed. To safety this bolt, safety wire is passed through the drilled hole in its head and secured by passing through other bolt heads.

## MACHINE SCREWS

These are used primarily to fasten nonstressed parts together where the principal loading is in tension, or else where the screw is much larger than the probable shear load requirement. Machine screws are threaded all the way up to the head and therefore do not provide a good shear surface. Machine screws, which are available in various kinds of heads, are installed with a screw driver. Where considerable tension is to be exerted by the screw a fine thread is preferable. These screws are available in brass, aluminum alloy, or cadmium-plated steel. They may be safetied after installation by the use of elastic stop nuts, lock nuts, or peening the end of the shank. Fillister head machine screws are sometimes drilled through the head and safetied by the use of safety wire.

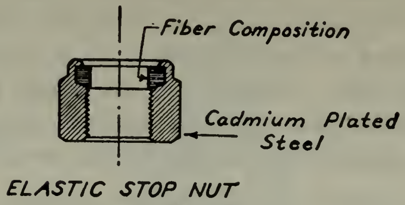


Figure 29.

## SHEET METAL SCREWS

These are made of cadmium-plated steel and have a thread which looks very much like a wood-screw thread. They are installed by use of a screw driver into properly drilled holes. They are generally used for fastening two sheets of metal together. The outer sheet is drilled with a hole large enough to pass the screw through it, the inner sheet is drilled with a smaller hole, and the sheet-metal screw cuts a thread in this inner sheet. Tightening the screw will draw the two sheets together. These screws are not safetied, but the friction in the thread keeps them from loosening easily.

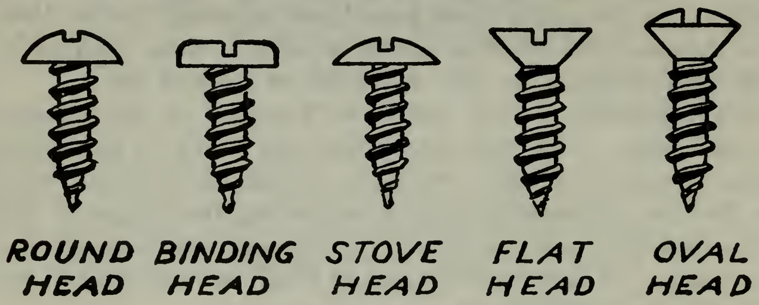


Figure 30.—Sheet-metal screws.

## CLEVIS PINS

These are intended for shear loading only. For example, they are used as a pin through a fork end of a turnbuckle and the tongue end of a fitting. These pins are made of cadmium-plated steel and come in various lengths and diameters. It is important that the proper length and diameter be used. They are secured in place by the use of a cotter pin. (See fig. 17.)

## TAPER PINS

These are used to fasten the ends of tubing to a terminal. This terminal may be part of a universal joint or in the form of an eye or a fork used for attaching the end of the tubing to another member.

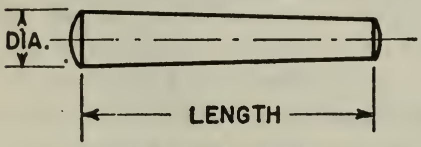


Figure 31A.—Plain taper pin.

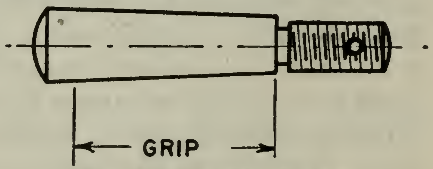


Figure 31B.—Threaded taper pin.

The terminal generally fits into the tubing for a short distance. One or more holes are drilled through the tube and the terminal and these holes are then reamed with a taper reamer so as to exactly fit the taper pin. The taper pin is secured in place by upsetting or mashing down the end of the plain type pin. The nut on the threaded pin is prevented from turning by the use of a special combination lug and washer or an elastic stop nut as shown in figure 32 may be used.

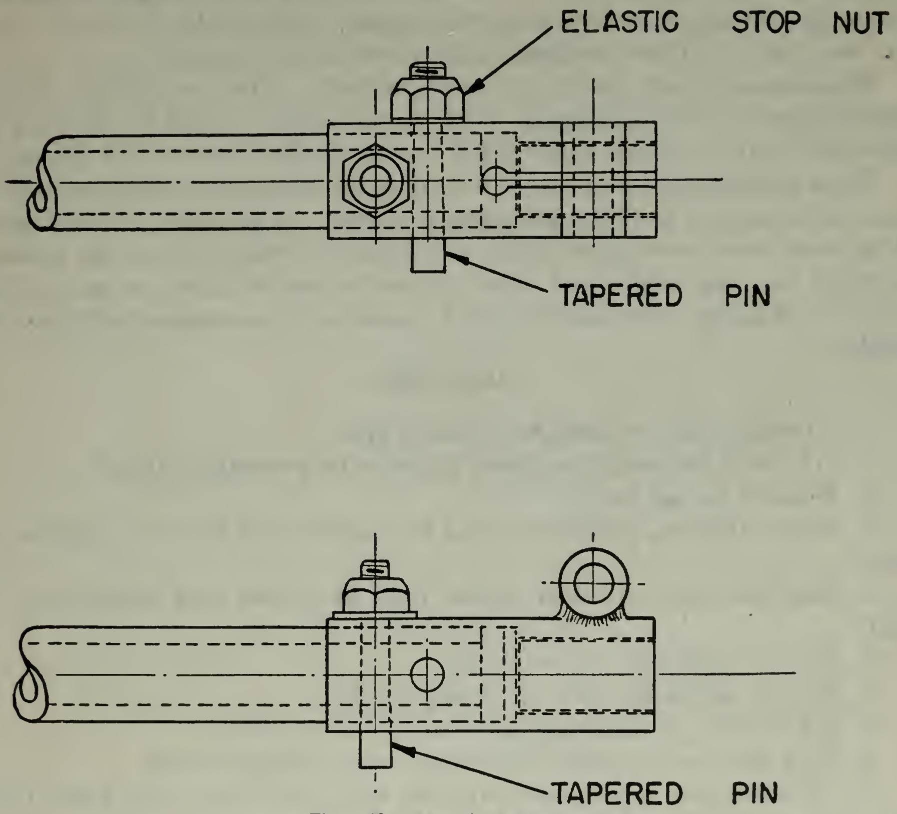


Figure 32.—Taper pin installation.

### LACING AND SLIDE FASTENERS

Occasionally it is necessary to open the covering of the fuselage or wings so that inspection and cleaning can be accomplished. Such openings are provided by the manufacturer. They are usually arranged with lacing eyelets or hooks or with slide fasteners so that very little effort is required to open or close the inspection opening.

## SAFETYING

All airplane bolts, nuts, and other fastening devices must be safetied properly so that they cannot come loose of their own accord. Safetied is one of the operations with which every pilot should be familiar since it will assure him of the continued integrity of the plane.

There are a variety of safetying devices, the most common of which are cotter pins and safety wire. Cotter pins made of brass or steel, cadmium plated, are inserted through the castellation of the nut and the pin hole of the bolt. This practice is followed on all of the aircraft bolt and nut assemblies, and should be used without fail as the method of securing important parts.

In place of cotter pins, elastic stop nuts described previously may be used in places where less security than a cotter pin can be tolerated. In cases where bolts are threaded into a casting or similar part and no nut is assembled, a drilled head bolt will be used. These drilled head bolts are prevented from turning by the use of safety wire which passes through the heads of two or more such bolts and secures them against accidental loosening.

Occasionally, jam nuts are used without other safetying. This is common practice for securing tie rods but may also be used for securing machine-screw nuts in places where other means of safetying are not convenient.

Some manufacturers up set the ends of bolts and machine screws and spread them out enough so that the nut cannot loosen. In this kind of installation a bolt or screw must be replaced with a new one if it is removed from the assembly. Safetying for turnbuckles and other parts of a similar nature is accomplished by the use of safety wire which should be installed in accordance with standard practice.

### *Questions*

1. Describe the preparation of casein glue.
2. Why is it necessary for glued joints to be accurately fitted?
3. What is a scarf joint?
4. What clamping pressure should be exerted on a joint on a spruce wing beam?
5. List the ways in which metal may be joined and discuss each one briefly.
6. Why are blind rivets required?
7. Why is aluminum alloy generally riveted?
8. What kinds of metal are suitable for folded seams?
9. Why are stressed parts never made using folded seams?
10. Explain how a bolt and nut with fine thread can exert more tension than with a coarse thread, provided the same torque is used.
11. How is it possible to use two washers, one one-sixteenth inch thick and the other one thirty-second inch thick, and still have the nut properly tightened and safetied?
12. How can you determine that a bolt is made in accordance with AN specifications?
13. Name four places where machine screws might be used on aircraft.
14. Where are sheet metal screws commonly used in aircraft structures?
15. List names of several metals which can be soldered.
16. Why not solder cracks in an exhaust manifold?
17. Why not braze stressed parts of a steel fuselage?
18. About how hot is an acetylene flame?
19. What precaution should be used when welding a gas tank which has developed a crack?
20. Why not gas-weld stainless steel sheet to construct a wing panel? What form of welding is preferred?

21. Why not rivet stainless steel wing skin?
22. How is welding heat developed in spot welding?
23. What is meant by "up set" as applied to a rivet?
24. What is a bucking tool?
25. When would a bucking tool be used against the head of a rivet?
26. What determines the length of an aircraft bolt?
27. How can the tension in a bolt be determined by a mechanic?
28. Can sheet metal screws be used to replace rivets in aluminum alloy structure?
29. Discuss the use of taper pins.
30. Why should they be used in place of bolts?

# Chapter V.—AIRPLANE CONSTRUCTION

It is the purpose of this chapter to give the student a general knowledge of structure and the construction of aircraft. The treatment will be in general principles which may be applied to specific airplanes.

## WING STRUCTURE

The structure of a wing of two-spar design is basically a framework consisting of two spars separated by compression struts, cross-braced by tie rods which are adjustable in length. Ribs are attached to the spars and are the members used to give the wing its shape and to transmit the air loads from the covering to the spars.

Metal wings generally differ from this type of construction because they have several spars or a cellular-type structure. In a metal wing the skin or covering may replace the bracing between spars. Drag load is then taken by the skin.

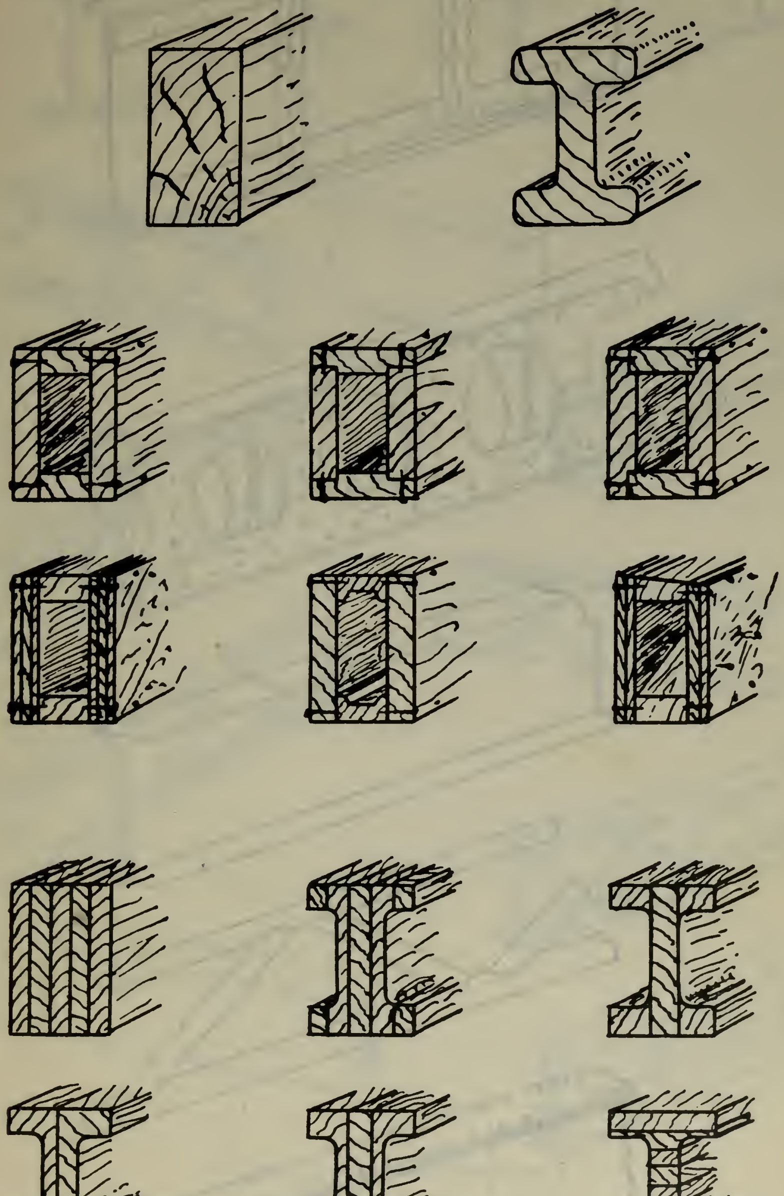
*Spars* or beams are members which are designed primarily to take bending loads. They extend the full length of the wing from root to tip and are the part to which ribs and compression struts are attached. These spars may be made of wood or metal. The wood most commonly used is spruce, and the metal most commonly used at the present time is aluminum alloy, although stainless steel is making an appearance.

Figure 33 shows several cross sections which have been used for wood spars.

Aluminum alloy and steel spars shown in figures 34A and 34B are used in the same way as wooden spars. The principal advantage of wood over metal is that it is cheaper and more easily worked. The metal spar lends itself to mass production and is more suitable for large fabric-covered or metal-covered wings. Metal also has longer life than wood and defects may be found more easily.

*Ribs* are used to give the airfoil its proper shape. They are made in special jigs which hold their shape within close tolerances. Structurally, the ribs are designed to take the air load from the covering of the wing and transmit it to the spar. In some wings certain of the ribs are designed to take the compression load between the front and rear spars, and in this case they replace the compression struts which would otherwise be separate members. The plain rib is called a *former rib*, the other is called a *compression rib*. These ribs are located uniformally along the spar with a spacing of from 4 to 20 inches. The 20-inch spacing is used for slow, lightly loaded aircraft. Rib spacing is determined by the wing loading and the strength of the rib.

Because of both the heavy loads and the necessity of an accurate shape at the leading edge, *false ribs* may be installed between the former ribs. These ribs run from the leading edge back to a short distance beyond the front spar. In many wings these false ribs are replaced by a sheet of plywood or aluminum alloy, which performs the same function.



TYPICAL WOOD SPAR SECTIONS

Figure 33.

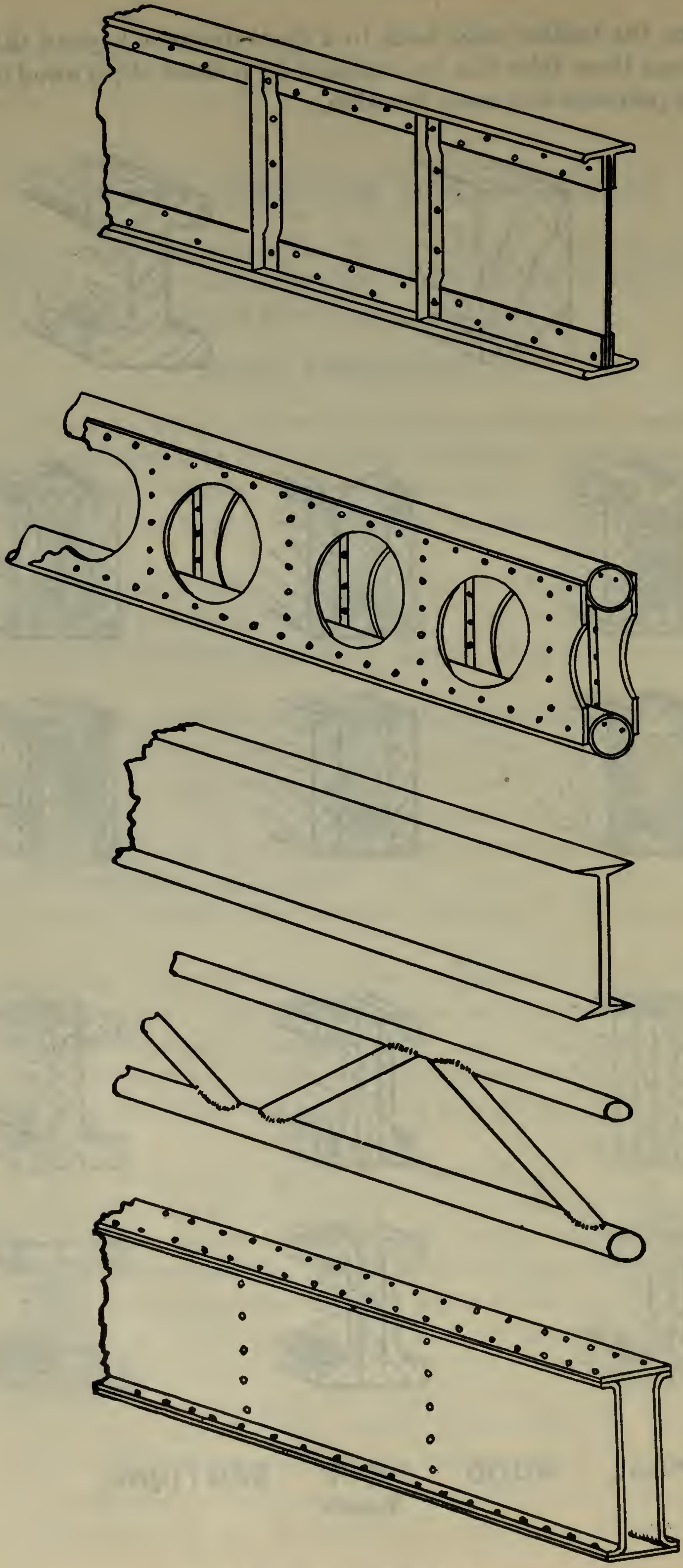


**Figure 34A.—Types of metal wing spars.**

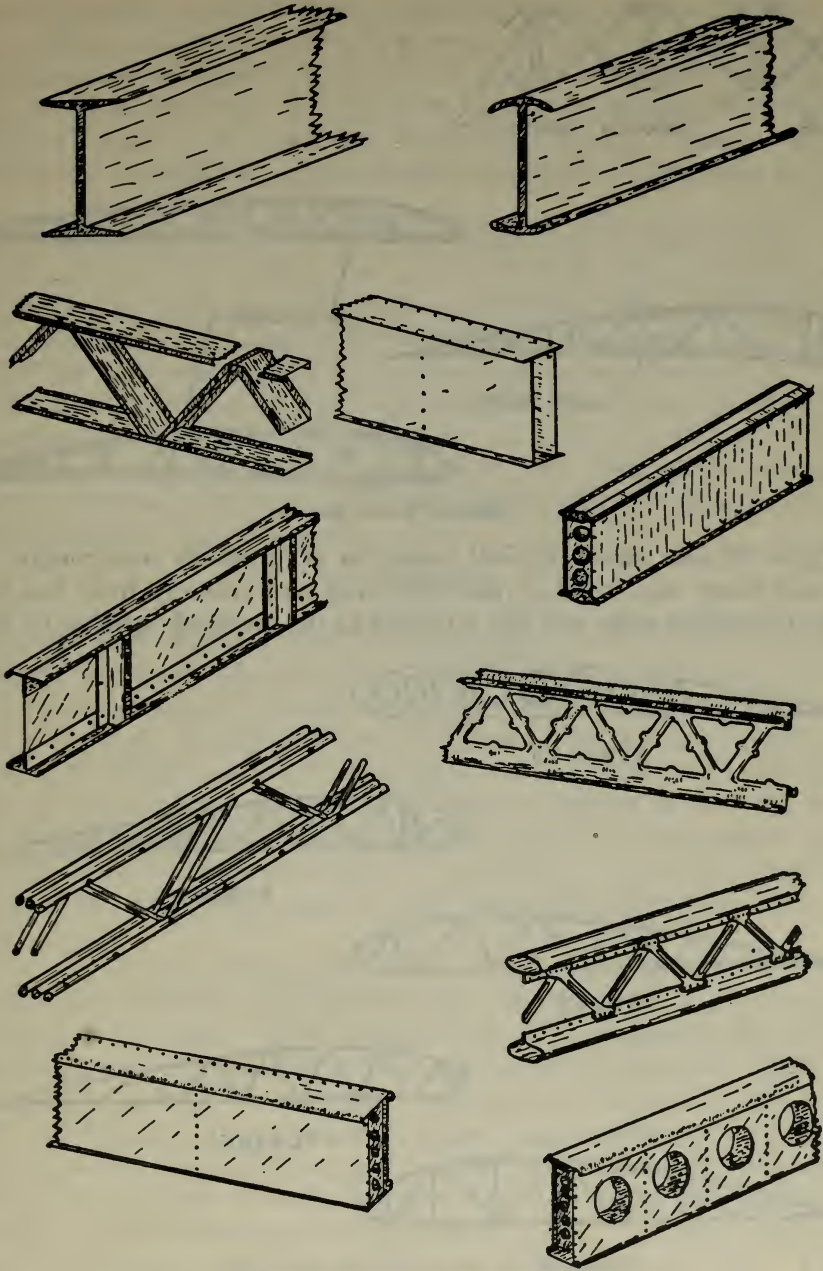


Figure 34B.—Types of metal wing spars.

Wood or metal may be used for rib construction even though the spars are of wood. They generally are made of metal for use with metal spars. Ribs are attached to the wooden spar by the use of small blocks, and by nailing and gluing. In metal construction a small bracket or clip is attached to the spar and provides anchorage for the rib. Ribs are weak laterally and therefore they must be supported to prevent sidewise bending. This is done by running two tapes, alternating above and below adjacent ribs and extending from the root to the tip. (See fig. 35.)

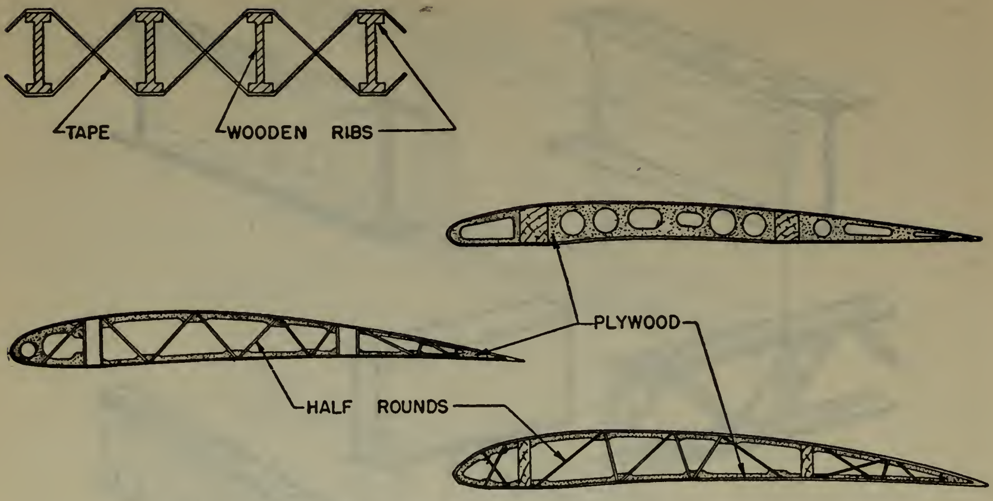
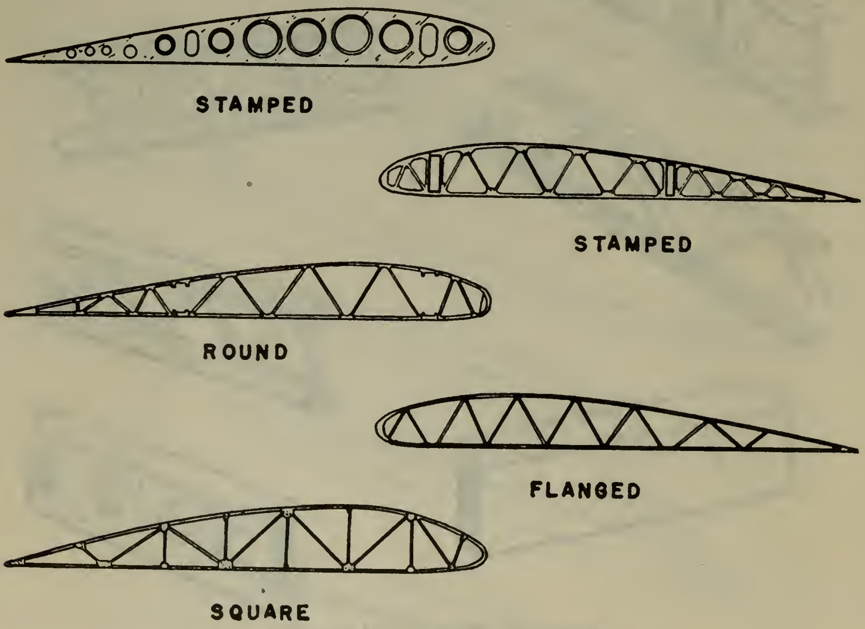


Figure 35.—Wooden ribs.

Figure 35 also shows typical examples of wood-rib construction. The upper and lower cap strips of these ribs run continuously from the leading edge to the trailing edge, and are attached to the plywood webbing by the use of casein glue and nails. The strut members of the rib are attached to the plywood webs also by glue and nails.



METAL RIBS

Figure 36.

Metal ribs generally are made of aluminum alloy and may be either of the stamped-out or the built-up type. Where a large number of the same size ribs are to be made the purchase of a stamping machine can be justified. This machine will cut and form the rib in a few operations and each rib will be identical to others from the same machine. Built-up ribs are similiar in construction to wooden ribs and are made in jigs which assure reasonable uniformity. The cap strip and struts of built-up metal ribs may be joined by welding or riveting.

These ribs are stiffened against lateral bending in the same way as wooden ribs.

*Leading and trailing edges* for wooden wings may be made of spruce strips attached to the nose and tail of the rib, respectively. In some instances the leading edge strip may be replaced by an aluminum alloy or plywood sheet which is attached to the cap strips of each rib and extends from the upper portion of the front spar around the leading edge to the lower part of the front spar. Trailing edges may be made of tubing U-shape channel or cable instead of the spruce strips. These are attached by metal clips to the tail of the rib. Particular care must be exercised in corrosion prevention at the trailing edge due to the collection of moisture in this part of the wing. Wings are ventilated through small holes near the trailing edge.

## COVERING

In order for an airplane wing to have its proper aerodynamic shape some *covering* which will maintain this shape must be attached to the ribs. Coverings may be made of plywood, metal, or cotton fabric. Most light airplane use fabric for covering. Heavy airplanes use metal covering almost exclusively.

**Fabric covering** is installed on wings in either of two ways—the blanket method, or the envelope method. The blanket method of covering requires that several widths of fabric be sewed together until the accumulated width is equal to the distance from root to tip. The length of each strip is large enough to extend from the trailing edge around the leading edge and back to the trailing edge.

Prior to covering, the ribs must be carefully inspected for rough spots. Sometimes the installation of cotton tape over the rib to protect covering from rough edges is desirable. If the internal finish of the wing would be damaged by the dope which is to be used on the covering, it is desirable to apply aluminum foil to the parts of the structure which are in contact with the covering.

*Blanket Method.*—In the blanket method the covering first is attached to the upper part of the trailing edge, by use of tacks which are later removed, and then drawn around the upper camber, then the leading edge and the lower camber for a second attachment at the trailing edge. The fabric stitcher then sews the covering all along the trailing edge using baseball stitch. He pulls the covering taut at every point. When completed this seam will extend along the trailing edge from the root to the end bow, and around the end bow to the leading edge.

*Envelope Method.*—The envelope method is best suited to taper wing coverings. The fabric is sewed into a blanket much like the blanket method, then it is cut to the proper pattern and sewed along the trailing edge and end bow. This will make an envelope or sacklike covering which is drawn over the ribs from the tip toward the root. Any looseness in the covering is drawn up by use of baseball stitch along the trailing edge.

To complete the covering, the fabric is sewed to the ribs by an operation known as *rib stitching*. Prior to rib stitching cotton reinforcing tape is tacked and held so that it will lie directly above the upper and lower cap strips. Waxed-linen stitching cord is threaded through a large needle. The end of this cord is secured at the trailing edge and the stitches progress toward the leading edge. A stitch is made by passing the needle through the covering from top to bottom, around the reinforcement tape, then through the covering and back to the top where a knot is made. (See fig. 38).

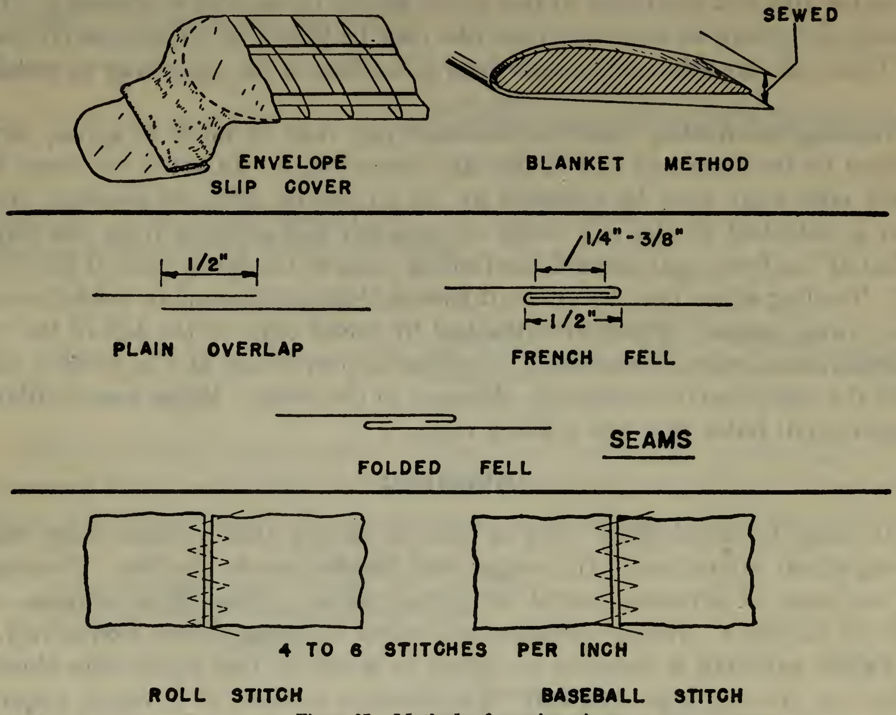


**Figure 37.—Methods of covering wings.**

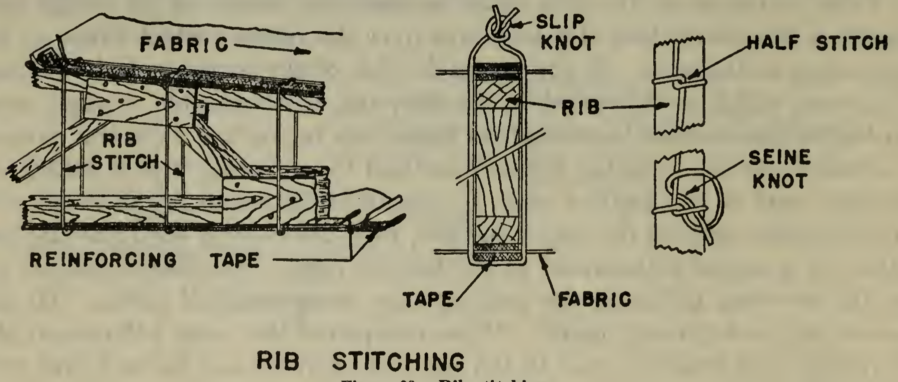


**Figure 38.—Rib stitching.**

Stitching secures the covering firmly to the rib and transmits the air load (suction) from the upper skin to the lower cap strip.

Fuselage covering and control surface covering is applied in much the same way as wing covering. The envelop method is used almost exclusively.

*Doping.*—After an airplane has been covered with fabric it is finished by the application of dope, which is a prepared material either of cellulose acetate or cellulose nitrate. The purpose of doping is to create a glossy, impervious surface on the fabric, to tauten the fabric, and to exclude sunlight, which will cause rapid deterioration of the cloth.

There are several procedures for the application of dope. Most of them consist of brushing on the first few coats and then spraying the last several coats with sanding and rubbing operations between coats.

When an airplane part is ready for doping, it is moved into a prepared dope room, where the humidity of the air is kept below a certain limit. This dope room must also have adequate ventilation to prevent too great a concentration of fumes, which would be injurious to health. After the part has been in the dope room until it reaches room temperature and dryness, it is ready for the application of a first coat.

The first coat almost always is applied with a brush so that the dope may be quite thick or viscous to prevent it from seeping through the cloth onto the interior wing structure. As this first coat is applied the fabric seems to lose its original tautness and become limp. Succeeding coats will be either brushed or sprayed on. Generally, after the second or third coat has dried the fabric tautness has increased beyond the original amount. Between the first and second coat, the wing tape, reenforcing patches, grommets, etc., are doped into place. The third and succeeding coats are generally applied with a spray gun. Sanding and rubbing down are done at the end of the 5th, 7th, 9th, and 11th coats, in the 11-coat finish. This sanding and rubbing is done with very fine sandpaper and is for the purpose of removing imperfections which otherwise would spoil the finished appearance. In the 11-coat finish, the last 5 coats are pigmented to bring out the desired color. In case semipigmented dope is used, all of the coats may be of this material. The time to dry between coats will be from 30 to 45 minutes. It is necessary that the relative humidity be maintained below certain limits. The rapid evaporation of the highly volatile dope cools the surfaces to which it is being applied. If the relative humidity is too high, moisture will be precipitated. This, in turn, causes "*blushing*" or whitening of the dope.

When it is necessary to make repairs to fabric-covered aircraft which do not involve enough doping to justify the use of a dope room, care must be exercised that this repair work is done during a comparatively dry day and during the dryest part of the day. This generally will be late in the afternoon.

## PLYWOOD COVERING

Plywood commonly is not used nowadays for covering, but many successful airplanes have been built and others may be built using plywood for skin. Plywood is attached to the framework by the use of glue, nails, and wood screws.

## SHEET-METAL COVERING

Smooth-surface sheet-metal covering has come into common use in the last few years for high performance and large transport type airplanes. This covering is built in as an integral part of the structure when the wing is made.

The sheets are riveted together as a general rule, though some designs contemplate the use of welding processes.

The principal draw-back to metal covering for all aircraft is that sheets thin enough for light aircraft would be difficult to handle and would be weak against blows tending to dent them. Also the method of joining aluminum alloy sheets by riveting is a costly and slow operation. Welded stainless-steel and plastic-type construction, which show promise of improvement in aircraft design are other forms of wing construction.

## STRUTS

*Struts* are members which are designed to take compression loads. They may be classified as follows:

(*a*) *Interplane struts.*—Employed to keep the wings apart and in their proper positions.

(*b*) *Drag struts.*—The main compression members of the internal bracing system of a wing which parallel the ribs. (When of heavy rib contour, they are termed compression ribs).

(*c*) *Fuselage struts.*—The braces between the longerons, which together with the longerons and brace wire if used, make up the fuselage structure.

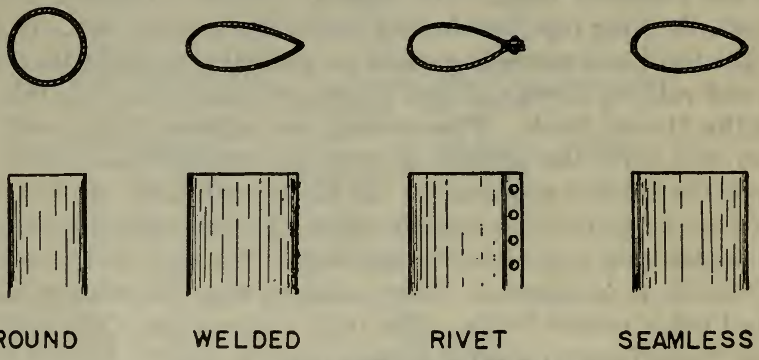


Figure 39.—Typical aircraft tubing cross section.

(*d*) *Tail plane or empennage struts.*—Structural members which, with brace wires support the fixed tail surfaces. In the majority of smaller airplanes only wires are used.

(*e*) *Engine mounting struts.*—Supports necessary for engine nacelles mounted between the wings.

(*f*) *Cabane struts.*—The compression members maintaining the distance of the center of the upper wing from the fuselage. The term is also applied to the struts employed to support a wing with overhang, as in semicantilever construction.

(*g*) *Landing gear struts.*—The members which transmit the loads of landing and takeoff from the wheels or floats to the fuselage.

(*h*) *Longerons.*—The primary continuous longitudinal members of the fuselage whose actions are often like those of spars instead of struts. This is because they are subjected to tension, compression, and bending loads and in addition have critical compressive loads when treated as being pin-jointed at the vertical strut attachment points.

Struts used in modern aircraft (fig. 40) are made of aluminum alloy or steel. Those which are exposed to the air stream are made with a streamline shape, or if round have a streamline fairing attached to them. Those enclosed within the structure of the plane may be made of round tubing or extruded shapes. Practically all aircraft tubing is of the seamless type.

Compression struts used inside of wings to hold the spars proper distances apart are generally round in cross section and have special fittings at each end to facilitate attachment, and provide for the transmission of load from the spar to the tube. Another function of the strut end may be the attachment of internal brace wires.

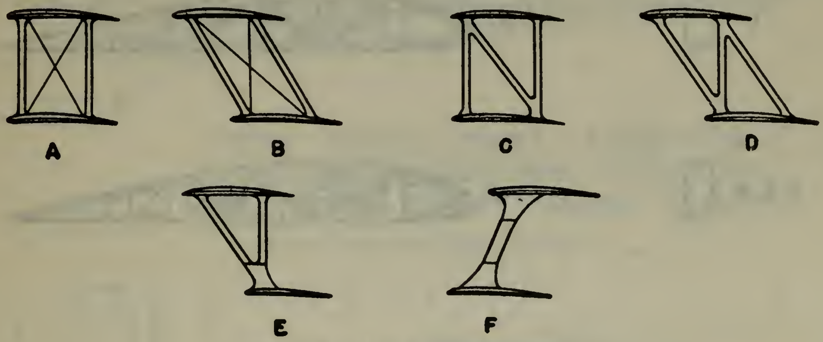


Figure 40.—Types of interplane struts.

Figure 41 shows ribs which are designed to replace compression struts. Internal brace wires will be discussed later.

The *truss type fuselage* is constructed with longitudinal members called *longerons*. These longerons provide the basic shape of the fuselage. They are held in this shape by fuselage strut members. (See fig. 42.)

Longerons may be of steel tubing, aluminum-alloy tubing, extruded aluminum alloy shapes, or combinations of these.

*Steel tube fuselages* are almost invariably of welded construction. Aluminum-alloy fuselages are riveted at the present time. They are constructed in special fuselage jigs, which assure uniformity of shape. The strut longeron frame may be braced by welding or riveting diagonal bracing struts in each bay, or else by the use of tie-rod cross bracing which is adjustable.

*Landing-gear struts* are generally made of heat-treated steel and may be round or streamlined. The tubing for retractable landing gear is almost always of round cross section due to the fact that these members are retracted into the fuselage or wing and round tubing is stronger per pound than streamlined. Nonretracting landing gears use streamline struts for all members except the shock strut, which is generally round tubing. This strut may be covered with a streamline fairing, especially on fast airplanes. (See fig. 43.)

*The engine mount* shown in figure 43 is of heat-treated steel tubing welded together before heat treatment.

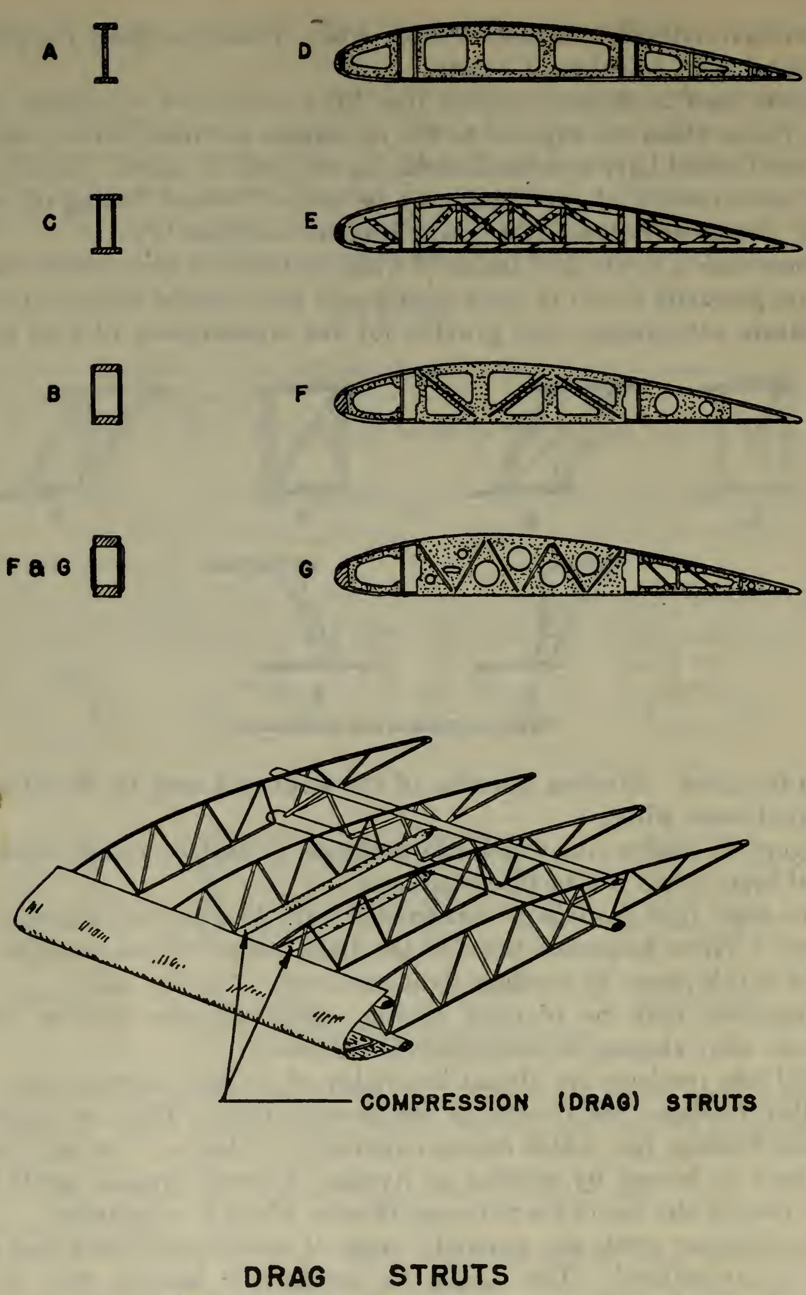
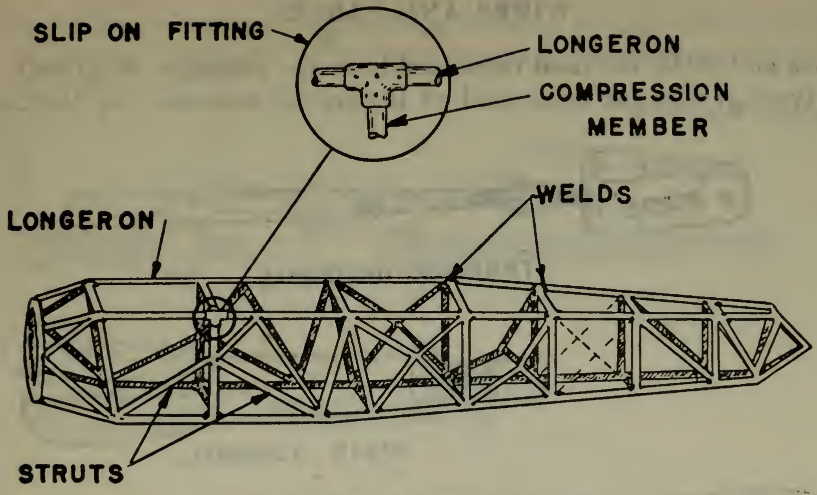


Figure 41.—Compression ribs and compression struts.



CROSS BRACE WIRES SOMETIMES USED TO STRENGTHEN STRUCTURE IN SOME TYPES (WHERE NEEDED)

Figure 42.—Truss type fuselage structure.

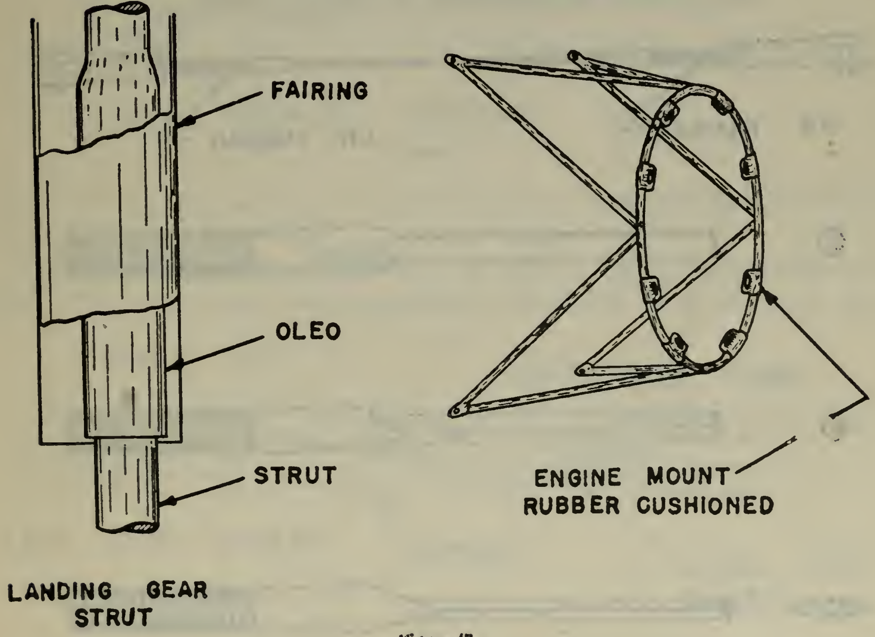
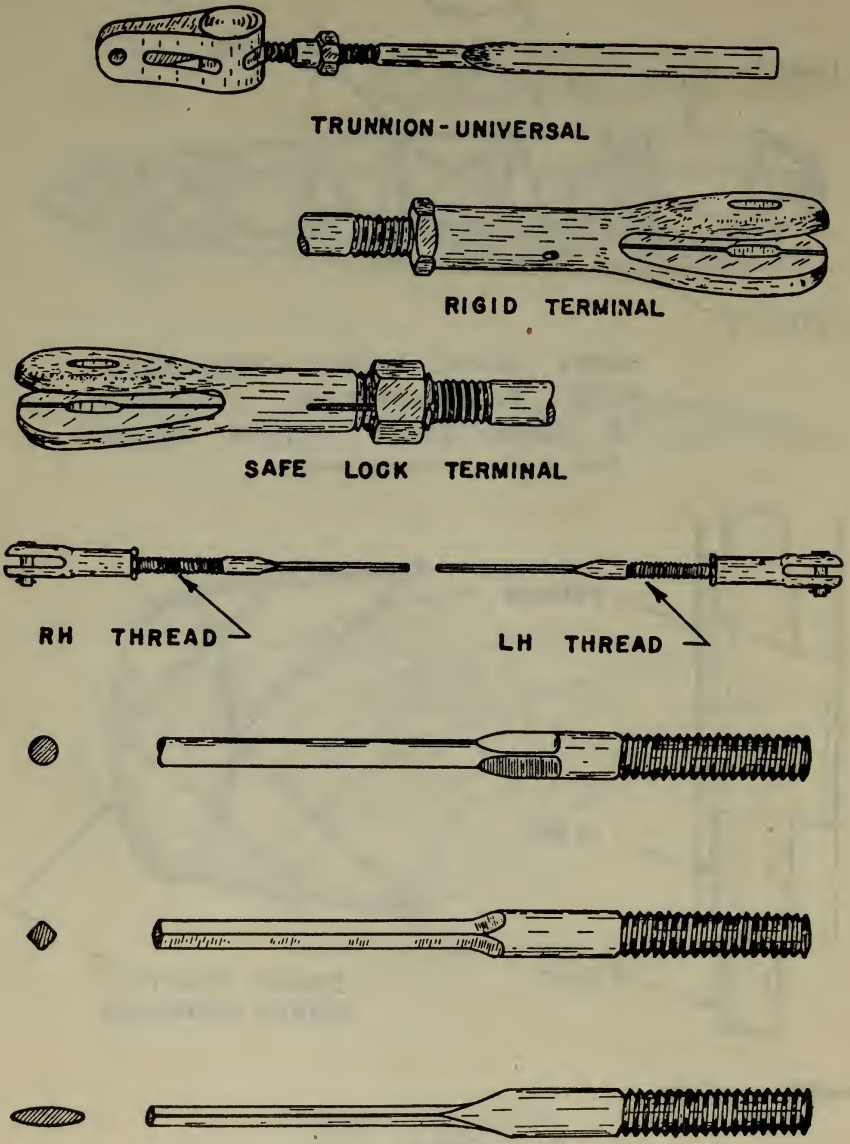


Figure 43.

## WIRES AND CABLES

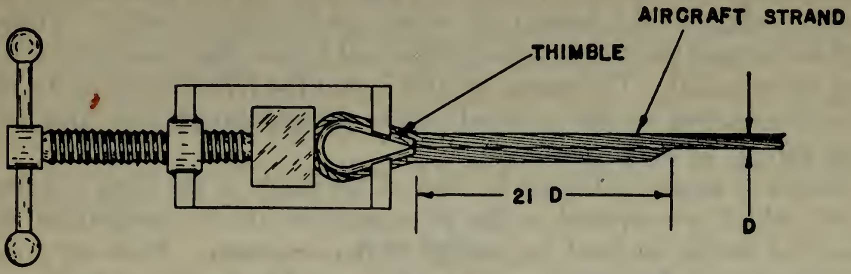
*Wires and cables* are used considerably in the structure of aircraft. The various types of wire and cable used at the present time are: (*a*) Hard-drawn wire of round section, termed *aircraft wire;* (*b*) tie rods of circular, square or streamlined cross section; (*c*) nonflexible cable, termed *aircraft strand;* (*d*) flexible cable, termed *aircraft cable;* and (*e*) extraflexible cable, termed *aircraft cable.*



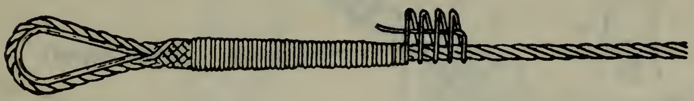
TERMINALS AND TIE RODS

Figure 44.

*Aircraft wire,* sometimes called piano wire, is a high strength steel wire tinned to prevent corrosion. It comes in various diameters on spools. This wire was used for brace work on aircraft but is now used mainly for safety pins and cowl fastening pins.

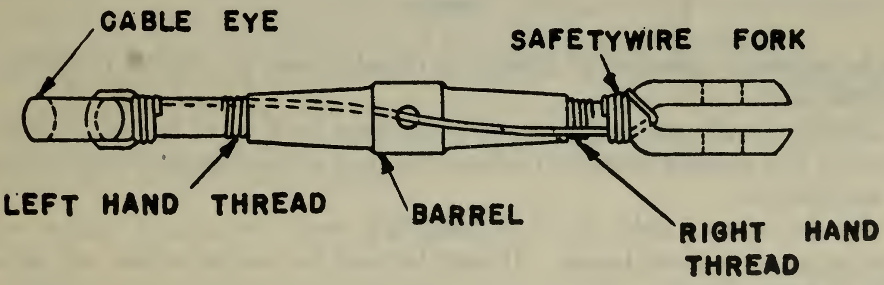


CABLE CLAMPING VISE



SPLICED TERMINAL AIRCRAFT CABLE

Figure 45.

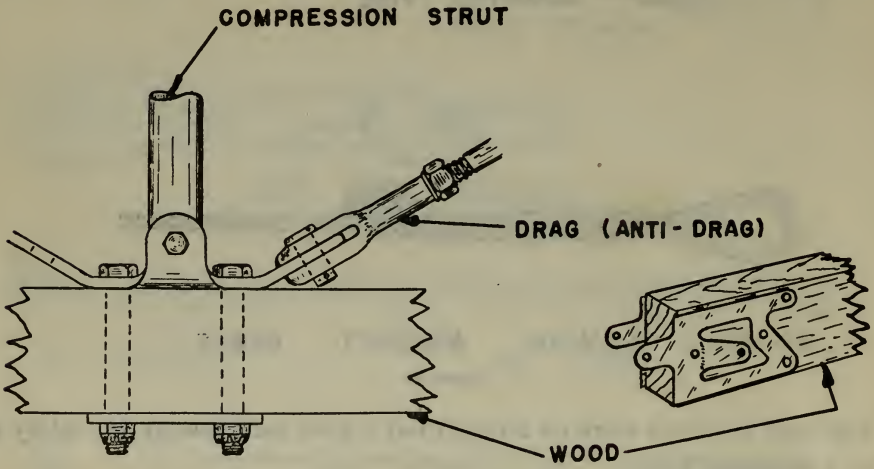


SAFETIED TURNBUCKLE

Figure 46.

*Tie rods* are cold-drawn swaged wire of circular, square, or streamline cross section. They are either cadmium-plated, tin-plated or of stainless steel to prevent corrosion. These rods are of predetermined lengths and are ordered from stock by length and diameter. They are threaded at both ends, one end with a right-hand thread, the other with a left thread so that when they are twisted into their terminals the distance between the pinholes of the terminals becomes shorter. A portion of the rod near each end is made square to receive the adjusting tool. No tool besides one approved for this work should be used because damage to the finish may result, permitting corrosion. These rods should be screwed far enough into the terminal to close the inspection hole in the side of the terminal. The reason for this is that the full strength of the rod will not be transmitted to the terminal unless enough threads are filled to bring the rod end up to the inspection hole.

Round or square rods may be used on the inside of the wing and fuselage. Tie rods which are exposed to the air stream should be streamlined in cross section and should be lined up parallel to the airstream. Rods are prevented from loosening of their own accord by the use of lock nuts on each terminal.



WING FITTINGS

Figure 47.

The terminals are secured to fittings in the structure by the use of clevis pins or clevis bolts.

*Nonflexible 19 wire cable* is occasionally used for bracing aircraft structures. Its use at the present time is so infrequent that no description will be given of this installation.

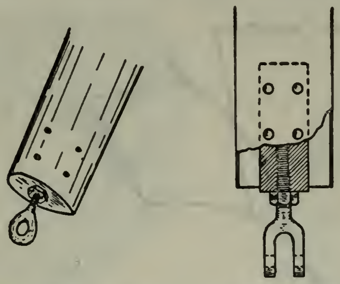
*Flexible aircraft cable No. 7X7* may be used for control cables which run straight or without bends. It may be used for rudder cables and elevator cables in some planes.

*Extraflexible aircraft cable No. 7X19* generally is used for control cable, and has replaced practically all other cable for aircraft use. In this type of terminal, the cable is passed around a thimble and clamped in a cable splicing clamp. The free end of the cable is frayed out into seven strands, which are woven into the main cable. After weaving, the rough portion of the splice is wrapped with waxed linen cord to cover it. A shackle, which is used to attach the cable to the control horn or other part, is passed through the spliced terminal and secured to the control horn by the use of a clevis pin, or clevis bolt.

The other terminal of the cable is made with the cable eye of a turnbuckle over the thimble. The turnbuckle fork end is attached to some part of the control system. The turnbuckle is used to adjust the tension of control cables. They should be safety wired after installation and adjustment so as to prevent accidental loosening during flight. A proper tool should be used in making turnbuckle adjustments to prevent tool marks on the barrel. Other kinds of cable terminals which do not require splicing are available and acceptable for certain installations. These terminals frequently use solder as the means of fastening the cable into the terminal.

## FITTINGS

*A fitting* is a small aircraft part which is used to join structural members together in such a way that the assembled parts are in position. Fittings may be made of any structural material which is used elsewhere in aircraft and generally consists therefore of 1025, 4130, stainless steel, or aluminum alloy. These materials in sheet form are used for built-up fittings inside of wings such as the drag-strut fitting in figure 47.



ADJUSTABLE INTER - PLANE STRUT ENDS

Figure 48.

Aluminum alloy castings and bronze castings as well as steel forgings are being used as fittings in various places such as the landing gear.

Fittings on the end of interplane struts are frequently made adjustable in length so as to make adjustments in rigging possible. Figure 48 shows this kind of strut end. In addition there are a large variety of miscellaneous fittings used in aircraft construction.

## FAIRINGS

*Fairings* are the parts of an airplane which are used for producing low drag shapes. For example, a strip of fairing made of aluminum is frequently installed at the place where the wing joins the fuselage to give a smooth junction. The truss type fuselage would have a rectangular shape if it were not for the turtleback and the stringers which hold the covering in an elliptical form. Turtlebacks and stringer assemblies may be classified as fairings. The streamline covering which is installed around the landing gear or landing gear wheels is also fairing. (See fig. 49.)

Fairings are not intended to carry any of the principal load on an airplane and are not strength members.

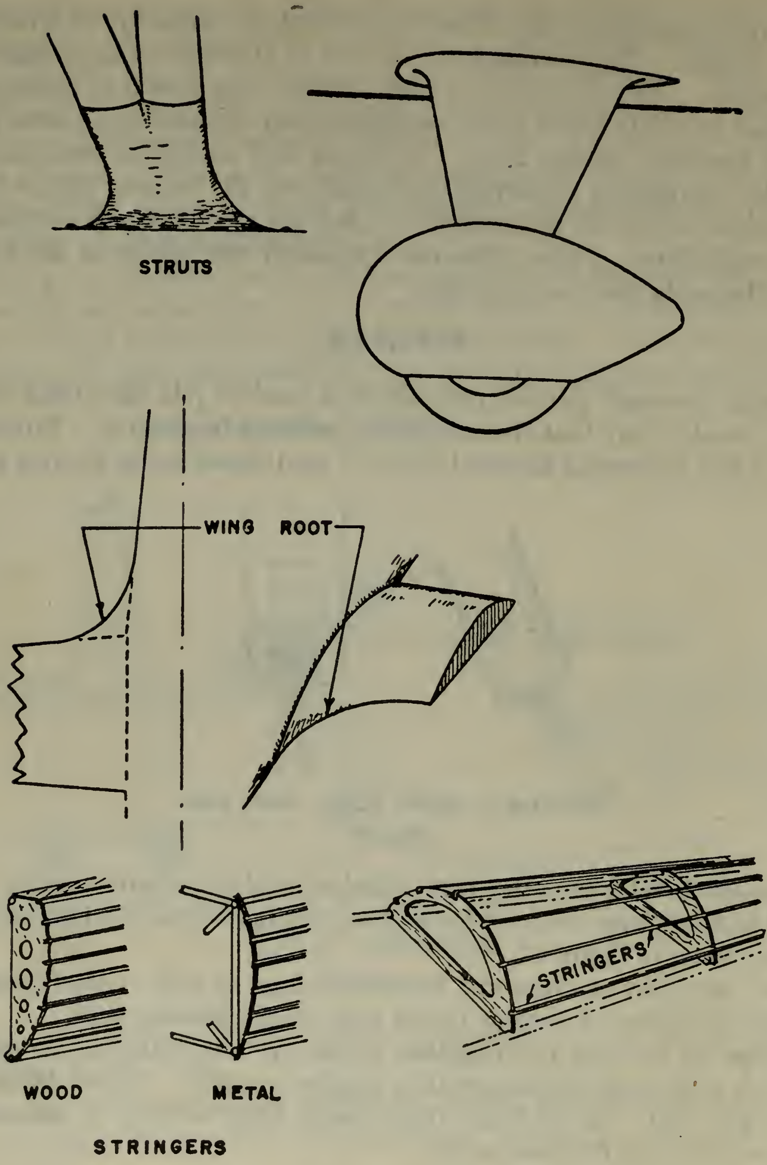


Figure 49.—Fairings.

## COWLINGS

*Cowlings* are sheet-metal covers which are easily detachable. They are arranged around the engine to enclose it and to direct the flow of air through and around the engine in a smooth manner. Cowlings are generally attached with quick-fastening devices so that they may be readily opened for inspection and service of the enclosed structure. In many types of airplanes a cockpit cowling is installed around the front and rear cockpit of the two-place airplane. This cowling is made of aluminum or aluminum alloy. It can be removed for inspection and maintenance of the controls and other parts in the vicinity of the cockpit.

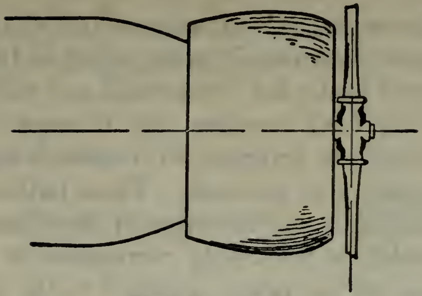


Figure 50.—Cowling.

## TANKS

*Tanks* for storage of fuel, engine oil, and cooling liquid in liquid-cooled engines, must be carefully designed, constructed, installed, and maintained so as to prevent accidental leakage of their contents. Several different kinds of

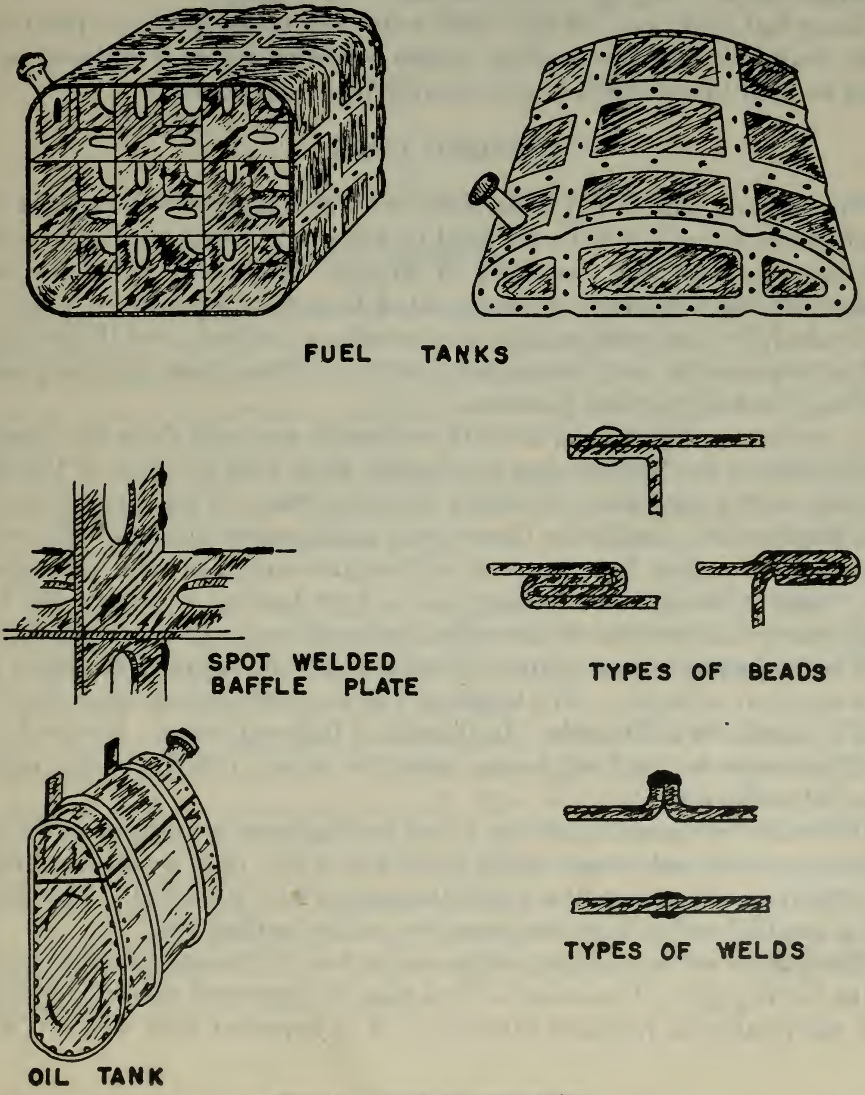


Figure 51.—Typical tank construction.

sheet metal are used for tanks, but aluminum and aluminum alloy are most common. At the present time considerable effort is being made to develop crash-proof and leak-proof tanks for commercial and military purposes.

General design of the tank requires that it have rounded corners when possible and that the interior be arranged with suitable *baffles* to prevent undue surging of the liquid contained in the tank. These baffles, attached to the skin of the tank, prevent distortion and vibration of the skin. Between the baffle-attachment points the skin is frequently corrugated or beaded to stiffen the walls. Supporting members are never attached to the tank but are generally arranged in the form of a sling to hold the tank in proper place. The suction line of the fuel system or oil system is attached to a low point in the tank so that all of the liquid in the tank is usable. In some aircraft, fuel tanks have been built integral with the wing and form a part of the wing structure.

In general, the method of joining the seams in tanks is by welding for aluminum and riveting for alluminum alloy.

Some fuel tanks are made so that water will collect at a low point which can be drained. This water often causes corrosion where it collects, so care should be used to determine if such corrosion has developed.

## LANDING GEAR

The *landing gear* is the understructure which supports the weight of an aircraft when in contact with the land or water and which usually contains a mechanism for reducing the shock of landing. It is also called the *undercarriage*. If the aircraft is to be operated from hard surfaces, a wheel type gear is used; if from snow, a ski type usually is utilized; and if from water, the float type gear is used unless the aircraft is a flying boat, in which case its main body or hull provides flotation.

A careful examination of aircraft commonly seen will show that basically the structure of the landing gear is of tripod form with the apex of the tripod attaching to the axle where it enters the wheel hub. This type of structure is the simplest conceivable for the average single-engine airplane. Exceptions to this will, of course, be evident in multiengine equipment and various other types, many of which have a single strut type landing gear. In the tripod arrangement, one member of the tripod, generally one which extends from the wheel to the fuselage longeron in the foremost position, contains the shock strut and is not fixed in length. The length of this member depends upon the weight which is placed on the wheels. In flight it is fully extended. During landing it will telescope as the load comes onto the wheel until the spring or other device takes the weight.

The other two members of the tripod landing gear are hinged at the upper attachment point and extend to the wheel axle where they are attached rigidly. The wheel axle will then follow a circular path as load is applied. This circular path is established by these two members of the landing gear.

Since there will be considerable movement at the bearing surfaces throughout the landing gear, it is essential that they be inspected carefully and lubricated adequately at frequent intervals. It is apparent that the two wheels will actuate separately, since they are independent structures. It is necessary that the brake linkage and cable be installed in such a way as to prevent inadvertent locking of the brakes due to landing gear deflection.

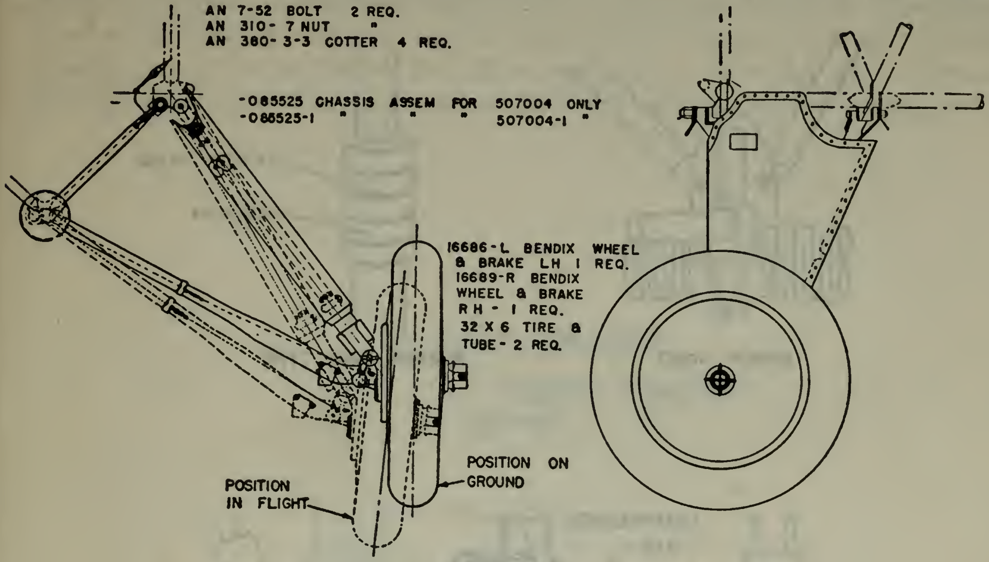

AN 7-52 BOLT 2 REQ.
AN 310- 7 NUT "
AN 380- 3-3 COTTER 4 REQ.
-085525 CHASSIS ASSEM FOR 507004 ONLY
-085525-1 " " " 507004-1 "
16686-L BENDIX WHEEL & BRAKE LH 1 REQ.
16689-R BENDIX WHEEL & BRAKE RH - 1 REQ.
32 X 6 TIRE & TUBE - 2 REQ.
POSITION ON GROUND
POSITION IN FLIGHT

**Figure 52.—Tripod type landing gear. (Typical assembly drawing.)**

## SHOCK ABSORBER

The purpose of the shock absorber is to prevent landing shock damage to the fuselage or body of the airplane. Pilots accidentally may cause heavy stresses due to landing on a rough portion of the field or to bad landings. If these stresses were not absorbed properly by landing gears they could easily cause failure in the airplane structure.

There are several kinds of shock absorbers now in use, one of which is best suited to a specific airplane. They may be divided into three classes: (1) Hydraulic and pneumatic; (2) rubber (disk, ring, cord); and (3) spring type (coil or leaf).

The low-pressure tire, used in some airplanes, replaces other means of absorbing shock. The principal difficulty with tires and even with some of the shock absorbers is that they do not dissipate the impact but store it and kick the airplane back into the air after a rough landing.

Figure 53 shows several types of shock absorbers. The *shock-cord* type, as the illustration shows, consists of several wrappings of this elastic material. As the landing load is applied to the axle this wrapping of rubber cord is stretched. In some cases internal friction is provided for with this type of absorber to prevent rebound, otherwise a large portion of the energy received from the rough landing will be returned to the airplane and cause it to jump or bounce. The principal trouble with rubber cord shock absorbers, however, is not a tendency to cause bounce but rather the rapid deterioration of the rubber which necessitates frequent replacements.

The use of *rubber disks*, or doughnuts, for shock absorbers has been prevalent in some aircraft. This type has some advantage over shock-cord types due to easier protection against oil and longer life. Its use on large aircraft is precluded, however, because of the limited travel afforded. It is often used in connection with hydraulic and pneumatic shock absorbers because of its ability to absorb energy.

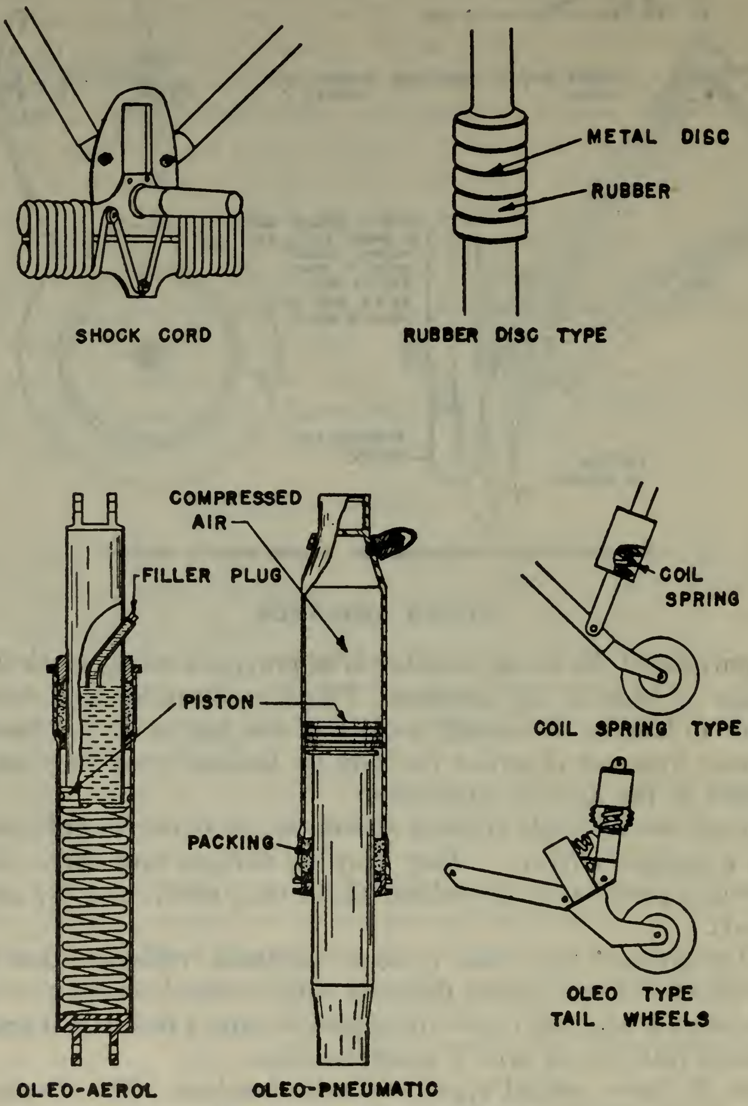


Figure 53.—Types of shock absorbers.

These disks are used with shock absorbers to take taxiing load and to cushion the landing after the normal travel of the oleo has been used up.

*Spring steel* shock absorbers are used in lighter aircraft with some degree of success. However, this type is applied best to the tail skid where the small absorption of energy by the spring can be tolerated.

### OLEO GEAR

The principle of the *oleo gear* is essentially the same as that of the recoil cylinder of a gun. The axle is connected to a piston which slides in an oil-filled cylinder attached to the framework of the landing gear. When the airplane touches the ground, the load on the wheel moves the piston in the cylinder causing the oil to be forced through a small hole. (See fig. 54.) The flow through this hole in the piston causes resistance which absorbs a large part of the impact. Since the weight of the airplane at rest on the ground would force the piston to the limit of its travel in the cylinder, it is apparent that the shock absorber would be of no benefit to the airplane when taking off, as the gear would not be in position to absorb any shock until the airplane was in the air and the piston had been moved by weight of the wheel and struts to the other end of the cylinder.

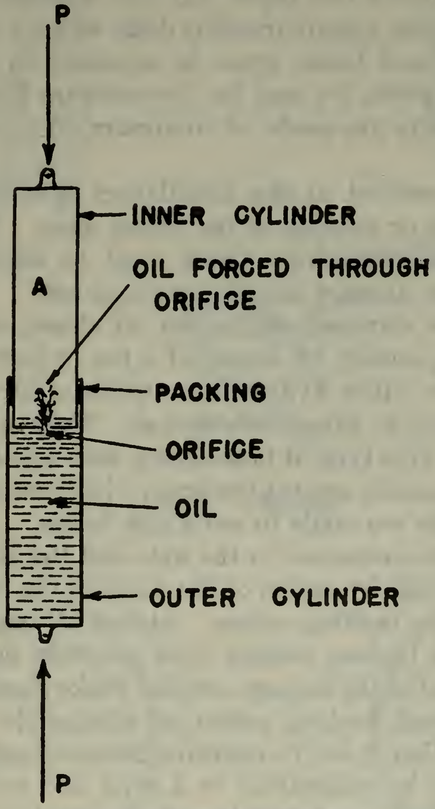


Figure 54.—Simplified shock strut.

To take care of this condition, a *spring or rubber buffer* is often provided behind the piston. This buffer is stiff enough to carry the weight of the airplane at rest on the ground, and some travel of the piston is then available to absorb the take-off shocks. This combination of spring and shock absorber differs essentially from that of an automobile, for on the automobile the spring takes all the direct impact and the shock absorber merely checks the rebound, while on the airplane most of the direct impact is taken by the shock absorber and there is little rebound.

The principle of *oleo pneumatic absorbers* is similar to the previous type. The air or pneumatic cushion is used instead of the spring to extend the piston and thus force the wheel down to keep contact with the ground. The impact is swallowed by the telescoping cylinder, and the air compression is dissipated through the oil, which checks recoil. Too fast a recoil is undesirable.

### WHEELS

*Wheels* are generally of two types: (*a*) The disk, and (*b*) cast type. The disk types are made from aluminum-alloy disks which are attached to the rim and the bearing. A steel brake drum is mounted on the inner side of the wheel. Cast wheels, which are used for low-pressure tires requiring wheels of small diameter, generally are made of aluminum alloy and have insert brake mechanism.

Care must be exercised in the installation of wheels so as to prevent binding of the bearing or rubbing of the brake shoe. Wheels are secured to the axle by some securing device which must be carefully safetied. They should be examined for damage and faulty alinement.

*Brakes*, which are standard equipment on almost all aircraft today, are operated by the pilot, usually by means of a toe or heel pedal on the rudder. These brakes may be either hydraulic or mechanical in operation and are similar in many respects to automobile brakes. They are usually of the internal-expanding type. This type of brake has a shoe which is mounted inside of the brake drum and expands against the drum when braking pressure is applied. Some of the cast wheels are made to use a disk brake.

Alternate disks are connected to the axle and the wheel. When pressure is exerted against the disk by action of the pilot on the brake pedal, friction is set up which makes the braking action. Almost all large airplanes are using hydraulically-operated brakes; smaller ones generally use mechanical brakes. Adjustment is provided in the linkage and the brake shoes so that a reasonable pedal movement and soft braking action are obtainable. The brake on each wheel is connected so that it can be operated independently of the other. It is important that brakes be maintained in a good and serviceable condition in order to assure safe handling of the plane during landing and taxiing.

*The pneumatic airplane tires* are similar to automobile tires in construction, using a soft rubber inner tube inside of a fabric ply gum rubber casing. Usually the casings are of 4 and 6 ply but do run from 2- to 12-ply casings for some airplanes.

Damaged inner tubes should be repaired by vulcanizing but blow-out patches and boots are not to be used as either will cause the tire to be excessively out of balance.

The proper inflation pressure is vital to the safety of the aircraft. This generally is molded in the tire wall. Underinflation of the tire allows complete collapse on hard landings resulting in cutting the inner tube and casing. Overinflation may cause bursting of the tire upon landing and in any event will put undue stress on the flange rim of the wheel, later causing blow-outs.

Sunshine, gasoline, and oil or grease are all harmful to tires. Tires should be kept in the shade if possible, and kept clean with soap and water. A clean hangar floor will do much to prevent deterioration.

High-pressure tires are usually on drop center rims (disk wheel). They carry from 30 to 60 pounds of air pressure, and are furnished with or without the thread.

Medium-pressure tires usually carry 15 to 30 pounds air pressure. They give a much better cushioning effect than do high-pressure tires. They are larger in size and create more air resistance, although with proper wheel fairing this is greatly reduced.

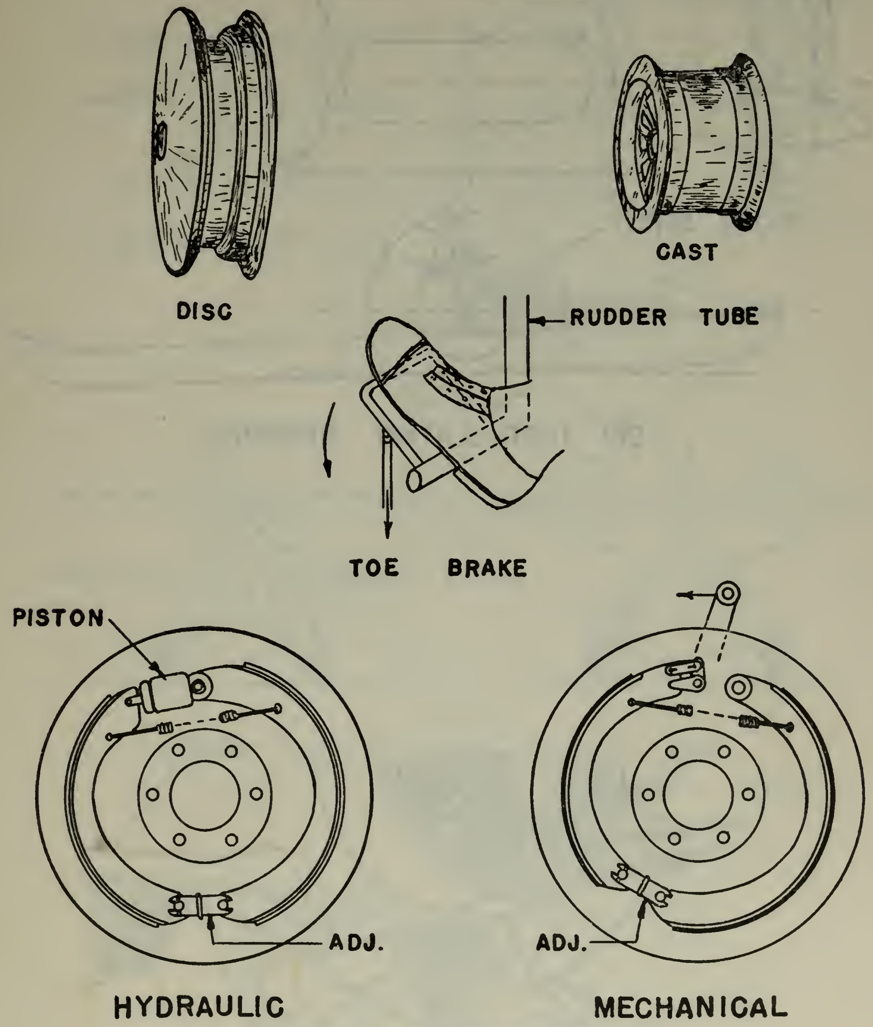


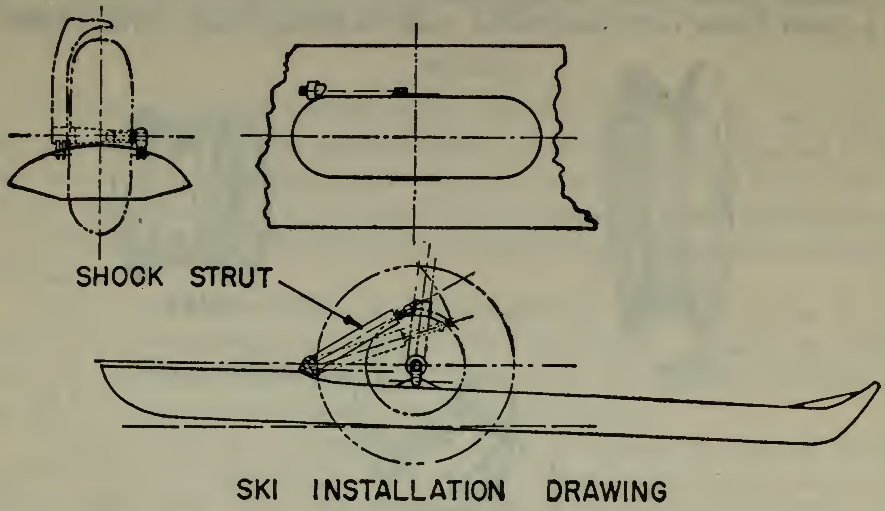
Figure 55.—Typical wheels and brakes.

Low-pressure tires carry pressures of 15 or less pounds. The tire is primarily designed to take up considerable of the land shock and to improve airplane performance on soft or rough ground. It is usually used with the standard shock absorbers but has also been used as the sole contact absorber.

## SKIS

The use of *skis* permits the airplane to be operated in deep snow where it would be impossible to operate with wheels only.

**A type of ski** has been developed in which the wheel is not removed from the axle for the installation of the ski. It is designed with an opening in it through which the wheel protrudes and is attached to the landing gear on each side of the wheel. The scheme is much more satisfactory for general operation of airplanes in snow than when equipped with skis only. This ski is an all metal structure.



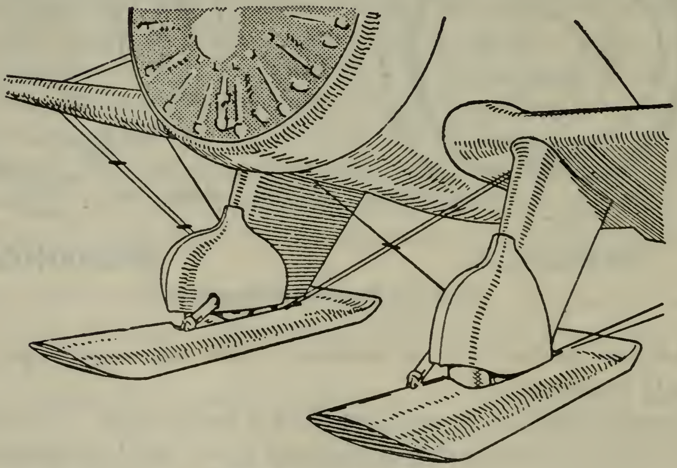
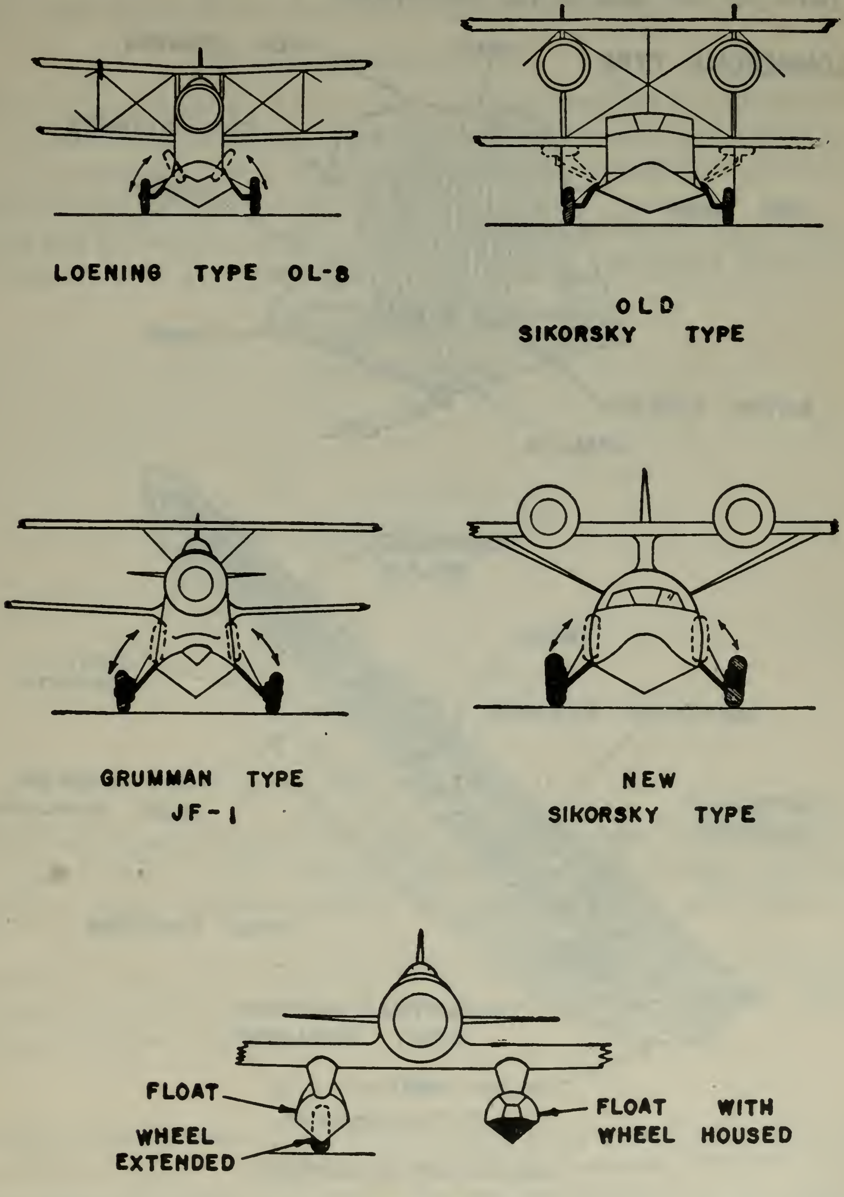


Figure 56.—Airplane skis.

## FLOATS AND HULLS

The four general types of seaplanes may be classified according to the arrangement of their flotation bodies. They are the single, the twin-float arrangement, the flying boat, and the amphibian. The single float and flying boats also have floats (pontoons) placed outboard for obtaining lateral stability on the water. Some foreign and American boats have used short stub wings or *sponsons* that project laterally from the *chine* (defined later) of the hull. An example is the Dornier boat. Some boats, such as the S–55 Savoia-Marchetti, were built with two hulls.



LOENING TYPE OL-8

OLD SIKORSKY TYPE

GRUMMAN TYPE JF-1

NEW SIKORSKY TYPE

SEVERSKY

Figure 57.—Amphibian-type landing gears.

All-metal construction is now used in floats and hulls, aluminum alloys, Monel metal, nickel, and stainless steel being the materials most used. Alclad is used in preference to aluminum alloy because of its greater corrosion resistance. This is augmented by using the anodizing process for all aluminum-alloy parts put into float or hull construction.

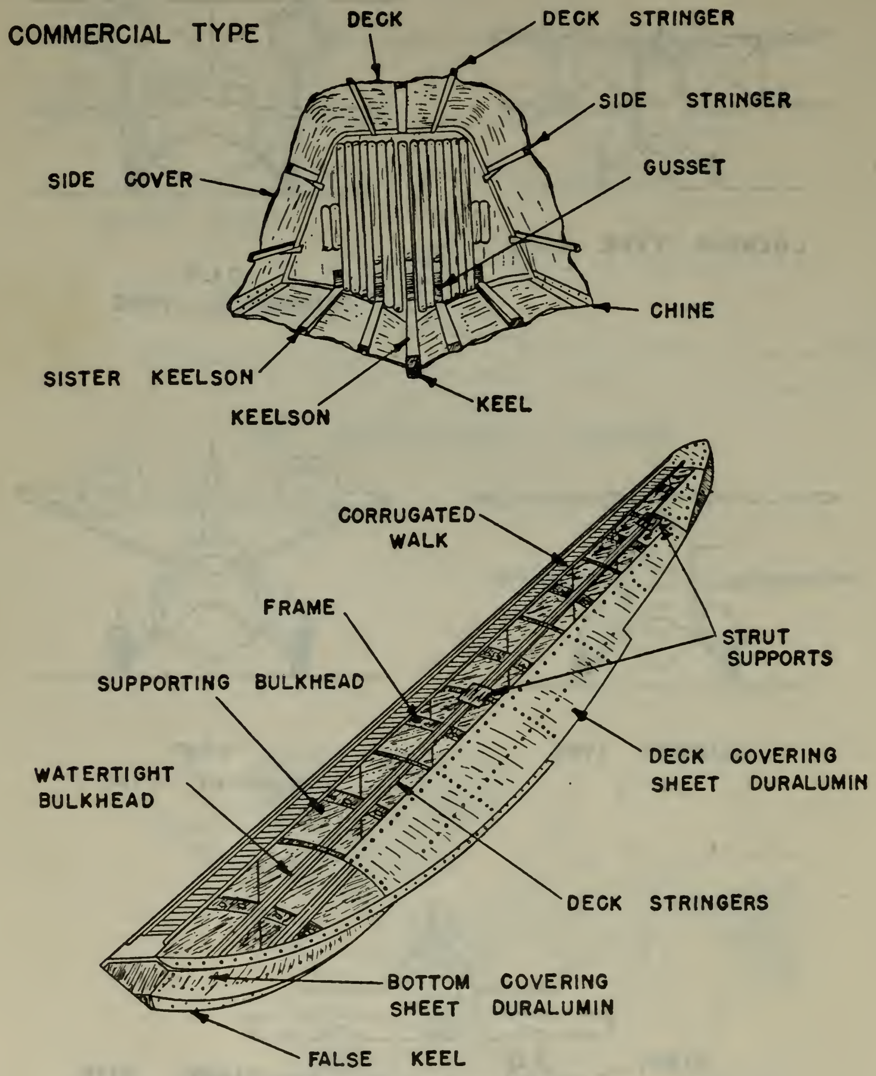


Figure 58.—Float nomenclature.

## KEELS AND KEELSONS

The *keel* of a float or hull is the principal longitudinal strength member of the bottom, being continuous throughout the centerline length from nose chine to transom. It is, therefore, essentially a spar, resisting bending and direct stresses. The *keelsons,* also termed bottom stringers, complete the longitudinal framing of the bottom and are distributed, as necessary, parallel to the keel on both sides. These too are ordinarily continuous and fall in the category of spars. The term *centerline keelson* is often applied to the backbone assembly of deck rail or centerline deck stringer, the keel, the vertical and diagonal braces, and the centerline bulkhead. This also may be considered a built-up spar with keel and deck rail for flanges and bulkhead for the web.

In metal construction the building of parts follows closely that which is used in ship construction as well as much of the nomenclature.

## CHINES AND STRINGERS

The *chine* is the longitudinal continuous strength member at each side of a float or hull which serves as a landing for both bottom and deck planking. It is made up in sections fitted carefully together. Open angles or channels are the usual construction sections adopted.

Stringers and keelsons are usually of the Z, **I**, bulb, or various angle shapes much the same as used in spars of the simpler variety. Extruded shapes of many sections are shown in figure 59. Float and hull fittings are for the most part the same as used in other parts of the aircraft. *Gussets* find extensive employment in tying members together and serving at the same time as stiffeners.

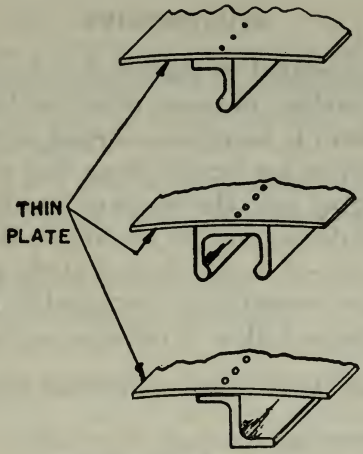


Figure 59.—Types of extrusions.

The essential factor for hull fittings is that they furnish a secure support and backing to transmit the loads to the proper strength members which receive large loads upon landing.

## FLOAT FRAMES

In the conventional design these frames preserve the curvature of the float deck from chine to chine. They are tied in with the keelsons, stringers, etc., at the same time affording a moment of inertia contributing to the girder strength of the float structure. The float deck is stiffened against local loads, such as a mechanic walking.

The shapes of these frames (floats and hulls) may be made by rolling, drawing, pressing, or beating, or by any approved shop practice.

As the weights of seaplanes run from 2 to 40 tons it is easily seen that no standard type of frame or parts can be made. Each individual type seaplane must be worked out for its individual capacities and desirable operation characteristics.

## FLOAT AND HULL STEPS

Float and hull steps are discontinuities in the bottom designed to break the suction effects by breaking the streamlines of water on the curved surfaces of the bottoms. The sharp break in the bottom surface calls for a step construction inherently designed for change in form, yet one able to withstand loads in the neighborhood of 8 pounds per square inch and insure complete watertightness. This latter is difficult since leakage is more likely to occur at the step than elsewhere, not only because it is one of the most highly stressed parts but also on account of constructional difficulties.

Considerable ingenuity and skill in detail design are necessary, as dural or Alclad cannot be hammered or beaten into the same complex shapes which are feasible with steel. Generally castings and blocks back up the sheet material and, with proper seaming, keep out the water.

## SPRAY STRIPS

Spray strips are incorporated on shallow float bottoms but strongly curved V bottoms turn down the sheet of spray which is characteristic with sharp V-bow lines. This metal strip is sometimes carried beyond the side of the float or hull. As a rule such strips are carried along that portion of the chine which would otherwise throw spray onto the wings or into the propeller. The hollow V-body plan sections hold down spray by tending to shoot it out laterally. The drag is high just before take-off, as the steep V at the keel drags with very little planing power, and a large wetted area is exposed to the water streamline. In spite of these disadvantages, hollow V bottoms are used extensively.

## METAL FLOAT AND HULL COVERING CONSTRUCTION

In all-metal construction, riveting is usually employed owing to the characteristics and gages of materials employed for both skin and framing. Fillister headed machine screws or bolts have been used, as also has welding on stainless steel hulls. As new methods are developed and proven, they will be incorporated in boat construction changes.

Both girder and monocoque construction may be used in floats and hulls but in the latter, semimonocoque design is usual.

### *Questions*

1. Sketch the cross section of an aluminum wing beam and indicate which portion is the flange and which is the web.
2. Give several reasons why wood is used for wing beams of small aircraft.
3. Describe the transmission of air load from the upper fabric to the wing spar.
4. Measure the rib spacing on several aircraft and explain why it may not be the same on each.
5. How is the curvature of the leading edge kept within tolerances?
6. Name four parts of a built-up rib.
7. Why is fabric covering generally used on light aircraft?
8. How is the interior of a fabric-covered wing protected against dope?

9. Describe the blanket method of covering an airplane wing.

10. Describe the envelope method of covering an airplane wing.

11. What method of covering is preferred for taper wings?

12. Why is it necessary to have a low humidity when dope is applied to a wing?

13. What is the reason for brushing the first few coats of dope?

14. Sketch the rib stitching for a wing

15. What is a strut?

16. In what ways would you expect interplane struts to fail?

17. Why is the compressive strength per pound of streamlined tubing less than round tubing?

18. Why are aluminum alloy fuselages riveted?

19. List the various kinds of aircraft wire and cable, and indicate the use of each.

20. How can you determine which end of a tie rod has a left-hand thread?

21. How are tie rods safetied against accidental loosening?

22. What is the meaning of X4130 when applied to steel?

23. If a fitting were made of X4130 steel, could it be welded?

24. What is a turtle back?

25. Would a turtle back be used on a monocoque fuselage?

26. Why will it be necessary for the interior of engine cowling to be streamlined?

27. How may welding replace riveting?

28. How is surge controlled in fuel tanks?

29. Why must a landing gear be inspected frequently?

30. Where will landing gear fail most frequently.

31. What would be the effect of low air pressure in a tire?

32. What would be the effect of low air pressure in a pneumatic shock absorber?

33. How is the piston of an oleo shock strut returned to unloaded position?

34. How is shock absorbed while taxiing?

35. Why are brakes actuated individually by the pilot?

36. What would be the effect if brakes were too sensitive?

37. Sketch the internal framework of a wing cell. Label the parts.

38. What is a false rib?

39. How are ribs supported to prevent bending laterally?

40. Sketch a biplane wing assembly and name the parts.

41. Why is round tubing instead of streamlined used for fuselage construction?

42. What is the purpose of the compression strut?

43. Sketch a turnbuckle and show how it is safetied.

44. Why should not an airplane be ground handled by pushing or lifting on fairing?

45. Make a sketch to show the baseball stitch.

46. How would a tear in fabric covering be repaired?

# Chapter VI.—ASSEMBLY AND ALINEMENT

In the preceding chapters the component parts of the airplane were considered. These parts, when joined together, form various structural units, termed *assemblies.* These assemblies in turn are joined together to form a complete unit or an airplane. Regarding the former, each component assembly is termed a subassembly. Obviously, the larger and more complex the airplane, the greater will be the number of stages in the assembly operation, that is, the more numerous will be the *subassemblies.*

Each airplane type will have its particular joining processes and assembly operations. The latter are of interest mainly as regards to the jig and fixtures which are employed to facilitate the work. While it is a purpose of this manual to touch on the use of forms and jigs in assembly, it is the finished assembly which will be stressed. This is because of the fact that the assembly shows the completed structural unit and the relationship of its various parts to one another. Until they are united, very little conception is afforded of their functions, arrangements, and distribution.

*Alinement* is a distinct phase of the assembly operation which deserves more than passing mention. The subsequent performance of the airplane, particularly with respect to stability and balance, requires that this be accomplished properly. Furthermore, improper *alinement* of a wing panel or fuselage may result in certain members being subjected to loads greater than those for which they are designed. Structural failures then may occur.

Consequently, the *rigging* of an airplane, as it is called, is of great importance. It is a necessary operation for both new and overhauled ships. It is also a maintenance function in certain of its phases, since use and abuse will bring about changes in angles and dimensions which result in improper balance.

Monoplanes (cantilever type) require no rigging since all attachments of center section to fuselage and outer panels to center section are jigged with no possible means of adjustments. Tabs are used to take care of any slight change in balance or weight.

A *jig* is a framework used in the assembly of structural parts. It must be constructed accurately and be provided with the necessary attachment lugs, clamps, and check marks to insure proper positioning and fastening of the individual parts for the welding, riveting, or other assembly operation.

Certain assemblies are too complicated for direct joining of all parts in an assembly jig. Recourse must then be had to *subassembly* jigs, or *fixtures.* Such is the case where a cluster of lugs or fittings occurs at a fuselage panel point. The individual fittings are made to fit a fixture which accurately locates their position with respect to each other and to longerons and struts.

## PRINCIPAL ASSEMBLIES

The complete structure of an airplane consists of the following four main units or assemblies: (*a*) The wings, (*b*) the fuselage, (*c*) the empennage, or tail unit, and (*d*) the landing gear.

The forms which these units take differ in various types of airplanes but their functions remain unaltered in spite of the differences in design.

## WINGS

*Function and location of the wings.*—The wing unit consists of the surfaces which provide lift necessary for support of the airplane, together with the struts, wires, and fittings which hold the wings in proper position relative to the fuselage and to each other. Attached to these surfaces and forming a part thereof are the ailerons, slots, tabs, and flaps, if used.

The wings must be placed on the airplane in such a position that the weight at the center of gravity of the plane will cause so little longitudinal unbalance that equilibrium or balance of the entire airplane is produced by the tailplane (stabilizer). As a general rule, it will be found that the center of gravity of the airplane will be no further aft on the mean chord of the wings than one-third the chord length from the leading edge. If the center of pressure is removed too far from the center of gravity, it is obvious that a large unbalance must be balanced by excessive tail loads and that the longitudinal stability of the airplane will be affected adversely.

*Terminology of the wings.*—Considerable ambiguity exists regarding the proper terminology for the wings of the airplane. Though a bird has two wings, the monoplane, which closely resembles it with respect to the lifting surfaces, is considered as having one. The biplane, in turn, is considered as having two wings. In general, a single wing is considered as the surface from tip to tip. But the term wing is also employed when referring to a part of the surface, with designating adjectives accompanying the expression. Hence, the biplane has a right lower wing and left lower wing. The term *panel* is that part of a wing which is built as a unit. Consequently, less confusion would exist if it were used with the term wing in its latter significance as right lower wing panel and left lower wing panel.

A wing *cell* is the complete assembly of wings and bracing members. An airplane with two or more superposed wings, has its cells divided into *bays*, each bay including all the structure between two sets of points of attachment of interplane bracing members. A biplane, for instance, may be constructed as single-bay, double-bay, etc., depending on the number of bays in the cell on either side of the centerline. For high-speed planes there will be no more than one bay.

A single wing panel may extend over one, two, or more bays, depending largely upon the size of the airplane, since convenience in construction and handling of a single unit are governing considerations. In airplanes up to 6,000 pounds a single panel almost always extends from the tip very nearly to the plane of symmetry. A short center section commonly separates right and left panels of the upper wing. With increased size, panels, termed wing walk sections, are inserted between the lower panels and the fuselage, and with still greater size two panels may be used on either side of the centerline designated as right upper outer wing panel, left lower intermediate wing panel, etc.

*Types of wing panel construction.*—A fundamental consideration controlling the structure of the wing panel is that of insuring a design upon which it is possible to make a stress analysis accurately. This limits the principal load transmitting members or spars to two, since with a greater number the proportion of the wing load carried by each is difficult to apportion and uncertainty exists in the results. Consequently, the *two-spar* type, which has the added advantage of simplicity, generally is used, although the *monospar* wing is used in some cases to advantage, and there are several good *multispar* designs. These all may be likened to stick and wire or trussed structures as regards design and construction, constituting a definite type in accordance with the number of spars employed.

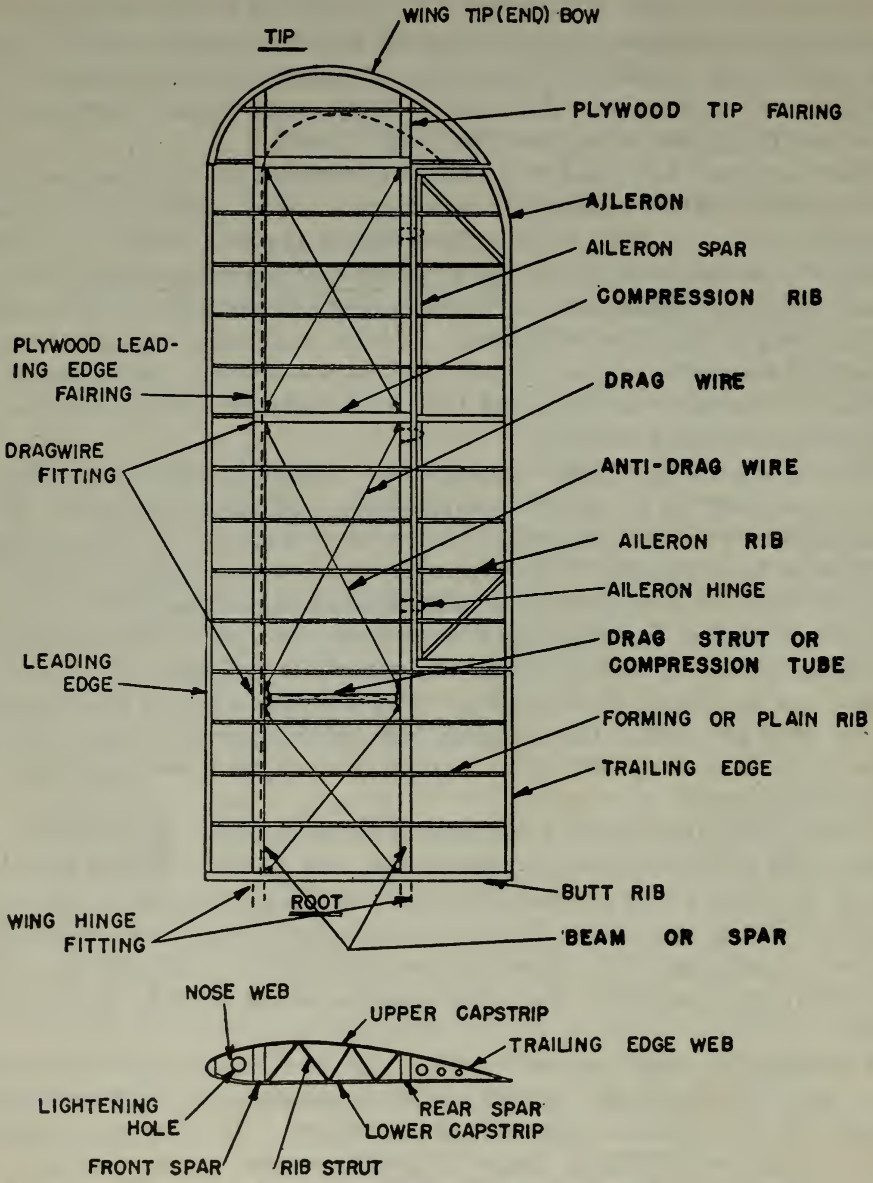


Figure 60.—Two-spar stick and wire wing panel.

Another type may be designated as the *veneer panel.* This differs from the above because fabric is replaced by stressed coverings of wood or metal.

There remains what might be termed the *monocoque* wing panel, made of wood, metal, or plastics. The impossibility of assigning definite stresses to a panel of ribs and cover makes this type of construction difficult. One way to build such a surface would be to construct and test a series of trial panels, for in this manner it would be possible to determine the lightest dependable structure suitable to sustain a given wing loading.

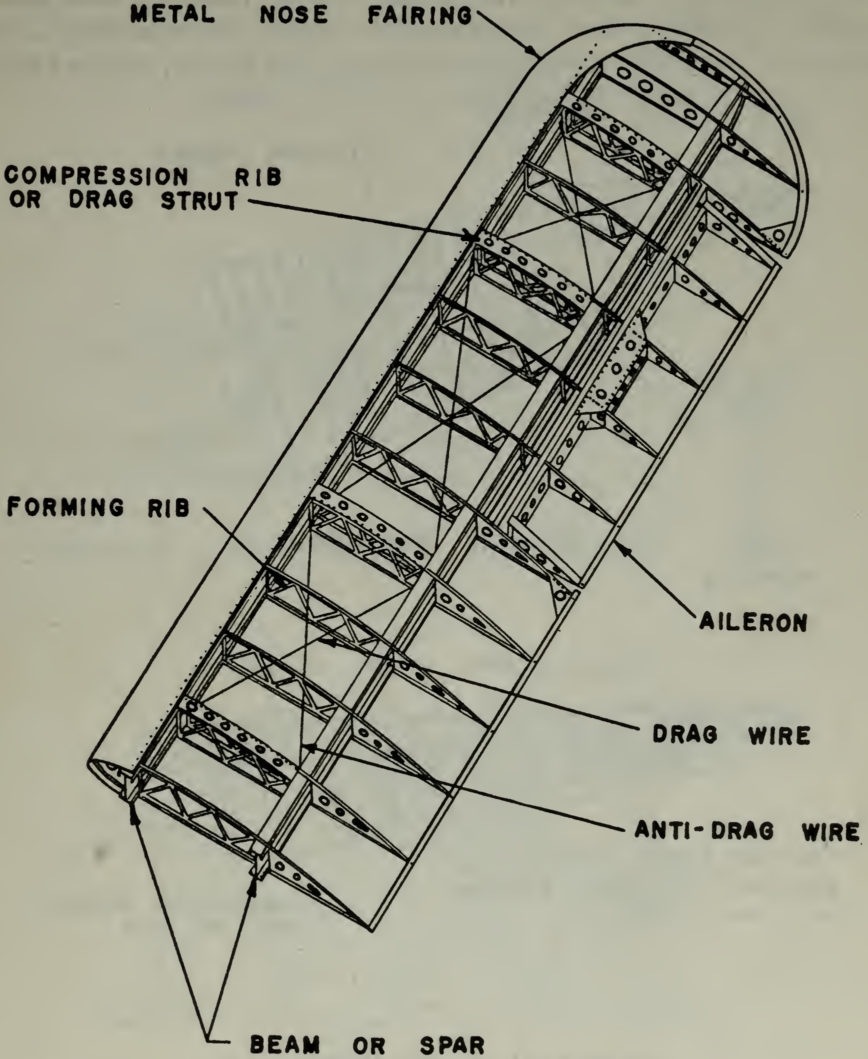
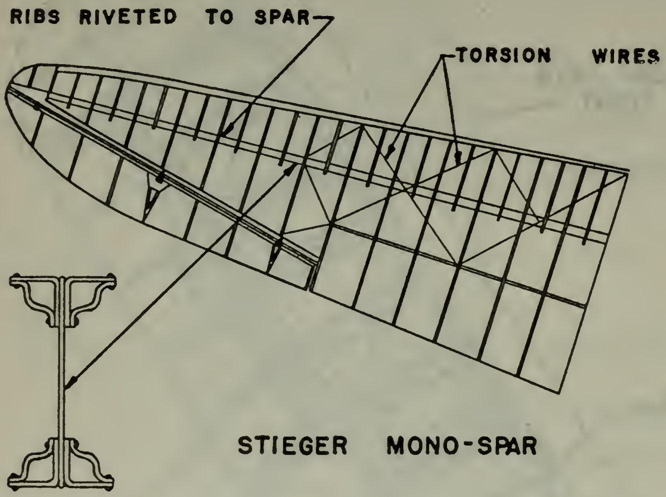


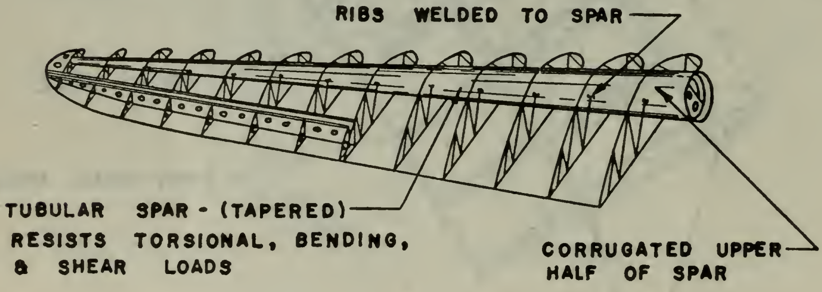
Figure 61.—Two-spar trussed type metal wing panel.

*Two-spar stick and wire wing panels.*—Figure 60 shows the internal structure of a typical wing panel of stick and wire construction. The main members are beams, known as the front and rear spars respectively. In biplane construction these members constitute the flanges of the front and rear trusses, the web members comprising the interplane struts and wires which attach to them.

The aileron is constructed in a manner similar to the remainder of the wing. The aileron spar runs parallel to the rear spar of the wing and is attached to it by hinges and fittings. The wing ribs in this section are divided into two parts at the rear spar, the trailing edge part of the rib being attached to the aileron spar. An end rib is placed at the inner boundary of the aileron to take the fabric pull.

The construction of the individual parts for the panel has been described previously. Naturally new developments, strength requirements, and the dimensions of the airplane, together with many other factors, impose variations from the wing described. The present tendency is to construct wings entirely of metal.




RIBS WELDED TO SPAR
TUBULAR SPAR - (TAPERED) RESISTS TORSIONAL, BENDING, & SHEAR LOADS
CORRUGATED UPPER HALF OF SPAR

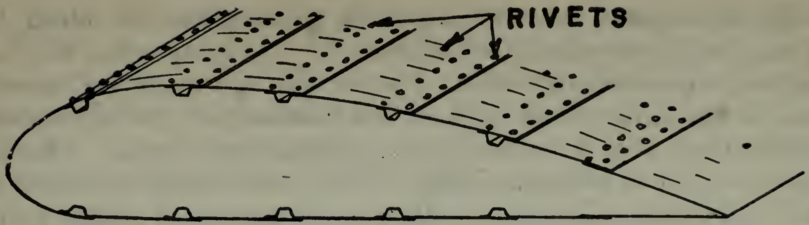
BLACKBURN — DUCANSON

Figure 62.—Mono-spar type wing panel.

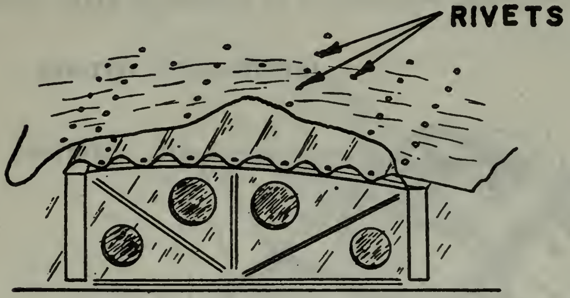
*Two-spar trussed metal wing panels.*—Wing panels of the two-spar trussed metal type follow essentially the structure described previously.

Typical examples are shown in figure 61.

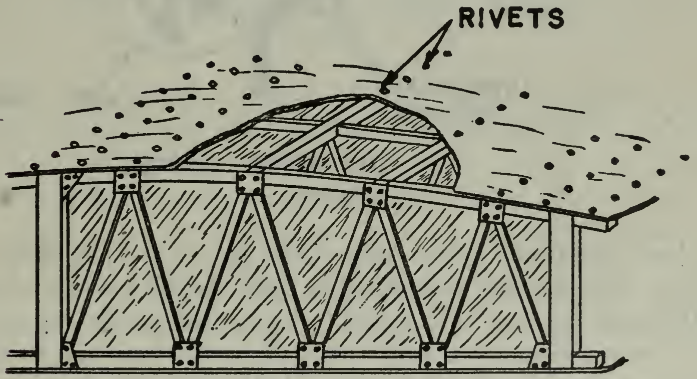
*Monospar construction.*—Monospar construction as illustrated in figure 62 has certain definite advantages for cantilever monoplane wings: structural weight will be reduced; stress calculations are simplified; and manufacturing



MONOCOQUE (STRESSED SKIN)



SMOOTH SKIN OVER CORRUGATED



SMOOTH SKIN OVER CONVENTIONAL WING PANEL

Figure 63.—Metal covered wing panels.

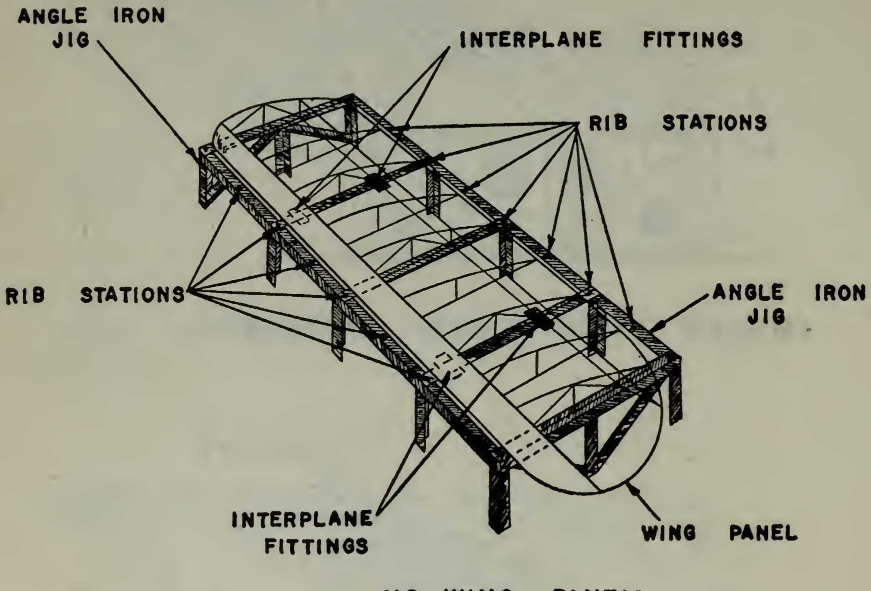
costs are lowered. The principal disadvantage lies in the reduction in the number of fuselage attachment points with the consequent greater load localization.

The single spar is placed in a position corresponding to the maximum depth of the airfoil. Compression ribs are placed at intervals and the whole spar is stabilized by tension members. The leading edge is a tension member as are also the diagonal brace wires and the antidrag member which, like the leading edge wire, runs parallel with the spar. The compression ribs form the attachment of the diagonal wires. Former ribs are employed between the compression ribs to distribute the load and maintain the contour of the cover.

A fairly thick wing is required, giving adequate spar depth. The available materials are steel or aluminum alloy. While not compulsory, taper in plan form and thickness are desirable both from viewpoints of weight saving and prevention of wing flutter.

*Multispar construction.*—Multispar construction, while not employed extensively, is, nevertheless, seen on several designs.

*Sheet metal covered panels.*—These panels are the same as the wood veneer panels except that the internal structure is of aluminum alloy or steel and the covering sheet aluminum alloy from 0.014 to 0.020 inch thick. As in the wooden wing, the spars are calculated to take the lift loads while the covering provides the drag bracing (ribs assist by tying the whole structure together). The spars in such a wing are usually tubes, or trusses built up of tubes, although some successful spar sections have been built up of steel or aluminum alloy channels of plate girders. Riveting is used almost entirely for the attachment of the metal covering to the internal structure. While portable electric multiple riveters and many unique tools have been devised for the work, it has been demonstrated that rivets driven by an eccentric press give 25 percent greater shearing strength than those driven by hand.



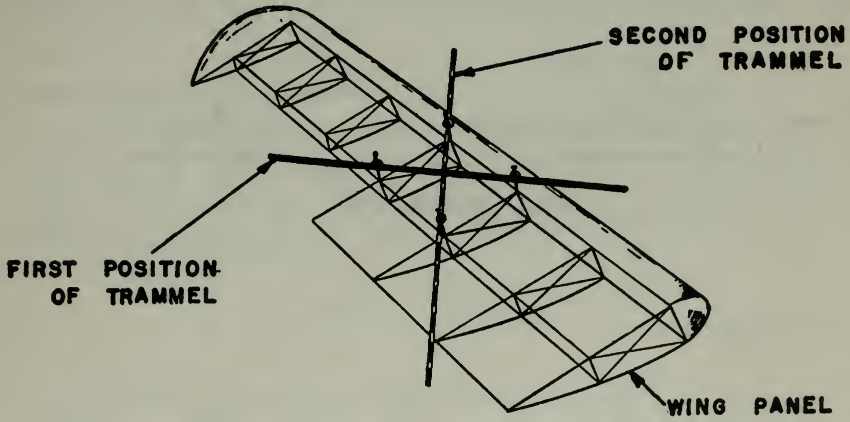
JIG WING PANEL
Figure 64.

The accompanying sketch (fig. 63) shows an example of such construction. The spars are trusses of steel tubing or aluminum alloy sheet and extrusions. The ribs are trusses of aluminum alloy tubes or U-shapes riveted to longitudinal members. The aluminum alloy covering reinforced by an extruded angle at the joints acts as a *capstrip.*

*Panel assembly process.*—The assembly of a wing panel is commonly done in a jig as indicated in figure 64, which shows the skeleton panel in position.

*Wing panel alinement.*—The jig-assembled wing panel will be in proper alinement and will remain so, provided the drag trussing is properly tensioned. Check marks are conveniently placed on the spars so that the corresponding tie rods can be *trammed* subsequent to removal of the panel from the jig and the assembly checked during later overhaul periods. The method of tramming is indicated in figure 65.

The panel is removed from the jig and the *trammel* adjusted to length so that the points will touch the check marks on the front and rear spars at opposite corners of a drag truss bay. The trammel is then shifted to the corresponding check marks and if its points coincide with the check marks, the bay must be rectangular and, hence, properly alined. If not, the drag truss wiring terminals must be unlocked and the length of both drag and antidrag tie rods varied until the trammel strikes both marks. This procedure is followed successively in each bay from root to tip of the panel. To insure against distortion in a section it is checked by sighting along the spars and leading and trailing edges. Each of these members should be straight throughout its length and this will be the case if reasonable care is taken in assembly and alinement.



TRAMMING WING PANEL

Figure 65.

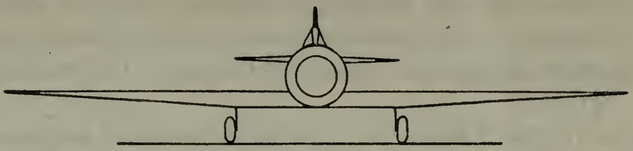
*Wing cell types and arrangement.*—The wing cell, whether monoplane or biplane, employs structural members having particular functions and hence particular names.

In *full cantilever* monoplane construction external bracing is eliminated. This is not the case in *semicantilever* types. Formerly the loads were carried in part by wires to a cabane structure above the wing but this method has been discarded in favor of *lift* struts as shown in figure 66.

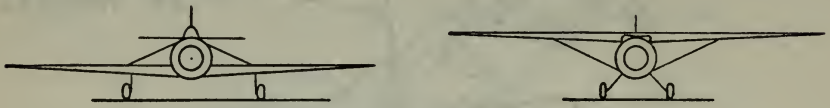
These struts are in *tension* during flight and in *compression* while the airplane is at rest.

In biplane construction, the *interplane* struts are the members which run vertical or nearly vertical between the upper and lower wings. The term strut is employed regardless of the fact that these members are sometimes in tension.

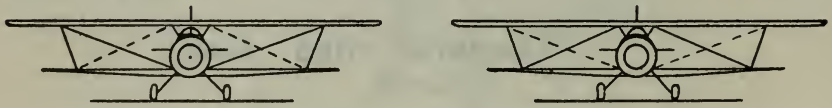
The trussing arrangement of the biplane is completed by a system of wires. The *flying wires* or *lift wires* which carry the load in normal flight run upward and outward from the fuselage as shown by the accentuated lines in figure 66. Without these wires the wings would distort in flight as shown on the left.



CANTILEVER

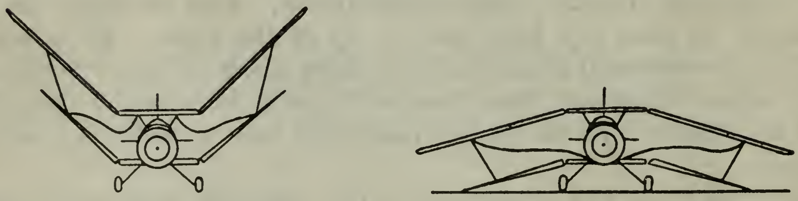


SEMI CANTILEVER



FLYING WIRES ACCENTUATED

LANDING WIRES ACCENTUATED



WHAT WOULD HAPPEN WITH NO FLYING WIRES

WHAT WOULD HAPPEN WITH NO LANDING WIRES

**Figure 66.—Wing cell arrangements.**

The *antilift* or *landing wires* run outward and downward, supporting the wings when the airplane is at rest as indicated by the accentuated lines. Without these wires, the wings would droop as shown.

One or more of the landing and flying wires will be inclined rearward in some airplanes to take the drag load. These wires are sometimes called external drag and antidrag wires.

## THE FUSELAGE

*Fuselage function.*—Design and construction of the fuselage represent difficult problems because of the many functions it must perform. It must provide adequate space for the powerplant, fuel and oil tanks, the crew, equipment, installation of controls, passengers, and cargo. Fuel lines, carburetors, strainers, magnetos, ignition leads, and instruments must be arranged so that inspection, repair, and replacement are accomplished readily. Points of attachments must be provided for the wings, tail surfaces, and the landing gear, arranged so that these units can be removed easily and replaced. Furthermore, the fuselage must be strong enough at these points to receive the lift load and landing loads. Finally, it should have a contour offering low air resistance and good vision.

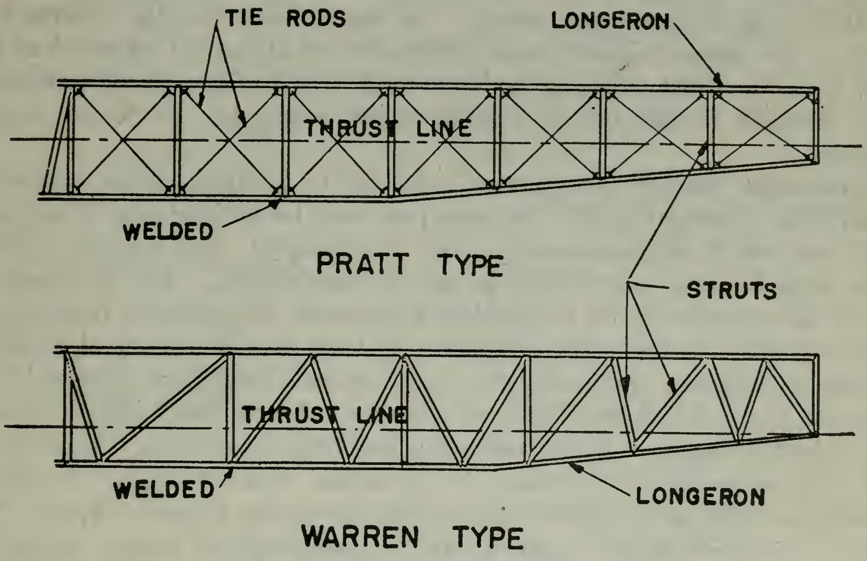


Figure 67.—Fuselage trusses.

*Types of fuselage construction.*—While fuselages may be classified with relation to the materials from which they are constructed, such as metal tube or veneer, it is more logical to designate them according to the manner in which the stresses are transmitted by the structure. So classified the types are then: (*a*) Truss, (*b*) semimonocoque, and (*c*) monocoque.

Truss-type fuselages include metal tube and veneer construction. In all variations of this type the primary strength members are the four longerons which are continuous from the engine mount to the rudder-post. The side trusses, of which the corresponding upper and lower longerons form the flanges, may have web members comprising vertical struts and cross brace wires, or tie rods as shown in figure 67. Such types are termed *Pratt trusses.*

On the other hand, the web members all may be capable of taking both tension and compression which is not possible with wires and tie rods. Types such as these are called *Warren trusses*. A typical example is shown in figures 67 and 42.

The top, bottom, and transverse trusses may be constructed in accordance with either of the above types of trussing, modified as necessary to carry concentrated loads, afford greater accessibility, and eliminate major interferences.

*Metal tube Pratt truss fuselage.*—The use of seamless steel tubing was prompted initially by the rapid deterioration of wood, both in service and in storage. The first transition was naturally the replacement of wood by steel or aluminum-alloy tubing, using wire cross bracing as before. Welded lugs serve to secure the terminals of the tie rods, used for cross bracing.

In lieu of welded construction, slip-on fittings may be used to secure struts and cross braces to the longerons as indicated in figure 42.

*Metal tube Warren truss fuselage.*—At the present time the Warren truss, owing to the greater rigidity and permanence of alinement afforded as compared with the Pratt truss, is used generally. In addition, weight saving for equal strength is effected in certain types owing to the fewer members employed.

*Monocoque fuselage* construction relies on the strength of the skin or shell to carry the principal loads. Monocoques may be divided into three classes (reinforced shell, semimonocoque, and monocoque), and different portions of the same fuselage may belong to any of these classes. The *reinforced shell* has the skin reinforced by a complete framework of structural members; the *semimonocoque* has the skin reinforced by longerons and vertical bulkheads but has no diagonal web members; and the *monocoque* has as its only reinforcement vertical bulkheads formed of structural members. Likely inaccuracies in design, together with weaknesses enforced by necessary openings and local reinforcements, constitute the principal disadvantages, though the maintenance difficulties imposed are serious drawbacks for some types. These include difficulties in the removal and replacement of tanks, engine, and equipment, and in the inspection and upkeep of fuel, oil, and water lines, and ignition leads and connections.

*Fuselage alinement.*—A fuselage of the Warren truss type is permanently alined in the assembly jig. Where slight distortion is evidenced after leveling longitudinally and laterally, it may be accepted or the structure cold bent to alinement if not warped or twisted too much. Because of its rigidity, the alined fuselage will maintain its form, barring a crash or unwarranted abuse in handling.

## THE EMPENNAGE

*Empennage terminology and functions.*—The empennage, also designated as the tail unit or tail group, comprises the control and stabilizing surfaces at the rear of the airplane together with the bracing struts and wires. The component surfaces are: (*a*) Elevator, (*b*) stabilizer, (*c*) rudder, and (*d*) fin.

The surfaces may be one or more in number and may be variously classified. The horizontal tail surfaces include the elevator and stabilizer, while the vertical tail surfaces comprise the fin and rudder. Again, the control surfaces are the rudder and elevator, while the stabilizing surfaces are the fin and stabilizer.

The empennage ordinarily is attached directly to the fuselage or boat hull, but in special cases of flying boats and amphibians better disposition and greater rigidity can be effected by supporting it on a tail boom.

The *elevator* is a hinged, movable, auxiliary airfoil, the function of which is to impress a pitching moment on the aircraft. It usually is hinged to the stabilizer.

The *rudder* is a hinged, movable, auxiliary airfoil, the function of which is to impress a yawing moment on the aircraft. It usually is hinged to the fin.

Although a *stabilizer* is actually any airfoil whose primary function is to increase the stability of an airplane, the term usually refers to the fixed horizontal tail surface of an airplane as distinguished from the fixed vertical tail surface. It provides longitudinal stability.

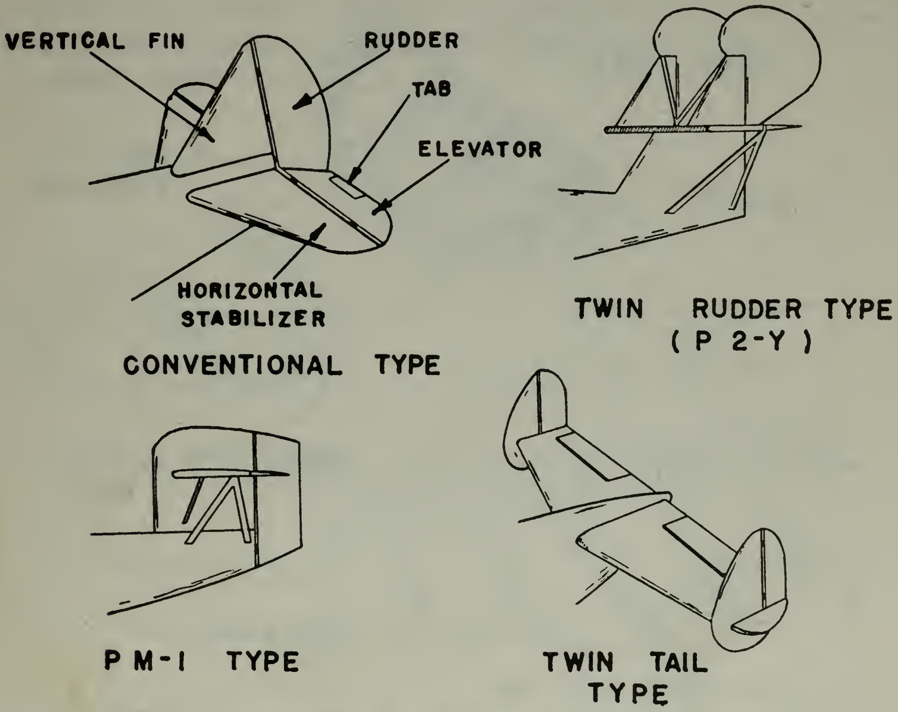


Figure 68.—Empennage types.

The *fin* is a fixed or adjustable vertical airfoil attached to an aircraft to afford directional stability.

*Types of constuction.*—The most common type of tail surface consists of a light metal framework covered with fabric or metal sheet. The contour is usually formed by tubes, either round or flattened, and the ribs are either small tubes or light sheet stampings.

The surfaces are externally or internally braced, depending upon the particular type of plane. External bracing creates parasite resistance but has a particular advantage of decreasing vibration. It also permits design of lighter weight surfaces.

*Elevators.*—The plan form of the horizontal tail surfaces follows, in general, the appearance of one of the following sketches in figure 69. It should be noted that the elevator is commonly made in two pieces having a notch between them. This provides space for the rudder since the latter generally is located to extend both above and below the plane of the horizontal surfaces.

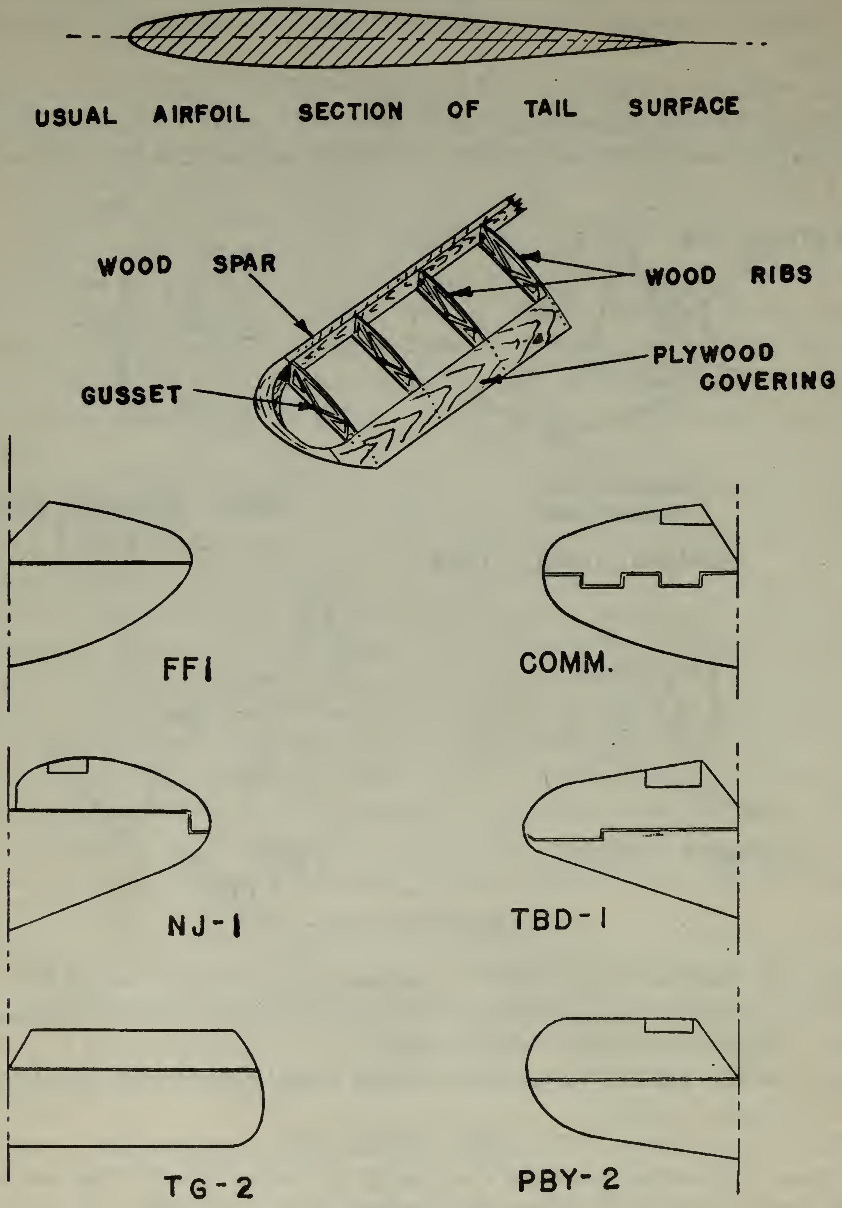


Figure 69.—Elevators.

All-metal construction for the elevator is usually tubular, chrome-molybdenum steel being the popular material.

Larger airplanes having thicker sections for the empennage surfaces use pressed-sheet construction, particularly for the ribs. Under such circumstances aluminum alloy is common. A typical elevator is shown in figure 70.

In lieu of the tubular construction, open channels of aluminum alloy may be used for elevator ribs as shown, combined with a built-up sheet aluminum alloy spar.

The elevator, regardless of construction type, should have its two panels (right and left) on a common spar or *torque* tube, or have the panel spars rigidly connected to form an integral structure. Where this is not the case a difference in tension on the control cables on opposite sides permits the separate panels to work up and down until serious vibration of the whole tail unit results.

*Rudders.*—The rudder is not symmetrical in plan form though usually symmetrical about the plane of symmetry of the airplane. This lack of symmetry is due primarily to limitations imposed by the structure, though attendant therewith comes a further distribution of area in the form of balance to reduce the forces having to be exerted on the rudder bar to correct for slipstream rotation effects.

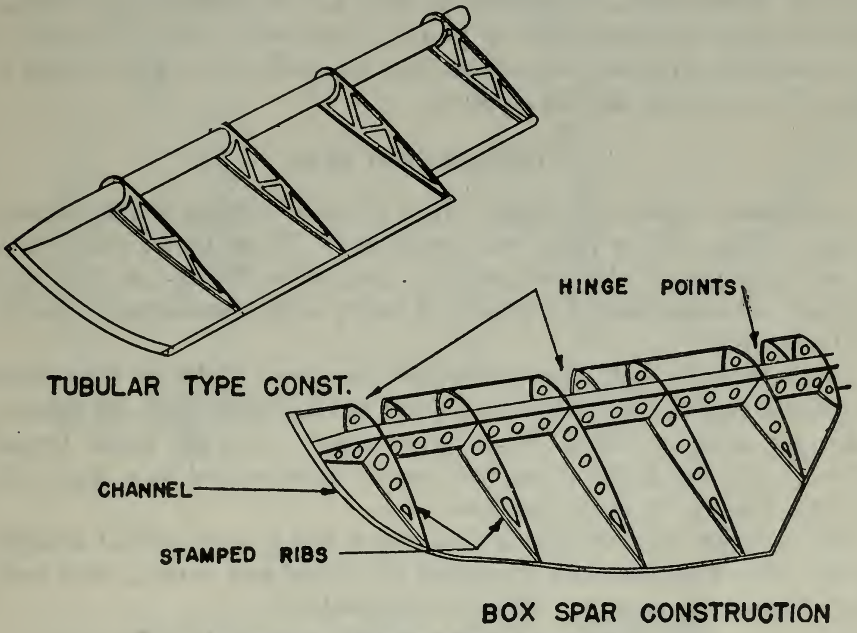


Figure 70. Metal type elevator construction.

In all-metal construction, tubing, shapes, and pressed sheet construction all find employment, although the latter is confined to the light alloys and is used primarily where the wings are built of the same material.

*Stabilizers.*—The stabilizer section ordinarily is symmetrical, as is the case of the movable surfaces. In general, present-day designs show greater thickness than formerly, due primarily to structural considerations. Greater structural rigidity and strength is afforded so that advantage may be taken of higher aspect ratios. Again the likelihood of vibration is reduced.

*Fins.*—The fin is important as a structural member as well as an aerodynamic element, since incorporated in it is the *rudder post* which supports the rudder and acts as a *kingpost* for bracing. Braces may be omitted where the fin spars are properly designed and built into the fuselage. In this event struts from the fuselage to the spars at the under side of the stabilizer are necessary. The fin is commonly of triangular or trapezoidal form or made with a slightly rounded leading edge.

All-metal construction of the fin follows, in general, that of the other tail surfaces.

*Empennage assembly and alinement.*—The first step in the assembly process is the installation of the stabilizer. The stabilizer is attached rigidly to the fuselage and ordinarily has a fixed positive setting to the thrust line. The fin is attached rigidly with a setting in accordance with erection plans relative to the airplane centerline. The rudder attaches to the fin by a hinge and to the fuselage by a hinge. The elevator is attached to the stabilizer by hinges.

No rigging of the surfaces on a modern airplane is required because of their cantilever construction. Controllable *tabs* are incorporated to correct any rudder-carrying tendency and to permit *longitudinal trim.* External struts incorporated on airplane tail surfaces may be altered in length to take care of minor adjustments of the tail surfaces.

## THE LANDING GEAR

*Landplane landing gear types.*—In a previous section of this manual construction of the various parts was considered. These parts, including wheel, tires and tubes, shock absorbers, struts, wires, axles, fittings, and tail skids and tail wheels are assembled in a variety of ways, each representing a specific type of undercarriage.

Much thought and experimentation has been given to that branch of aeronautical engineering involving aircraft landing gear since the days of wire wheels and straight axles. Fixed types show a marked trend toward the cantilever with shock-absorbing mechanism incorporated in a single strut as within the fuselage or wing structure.

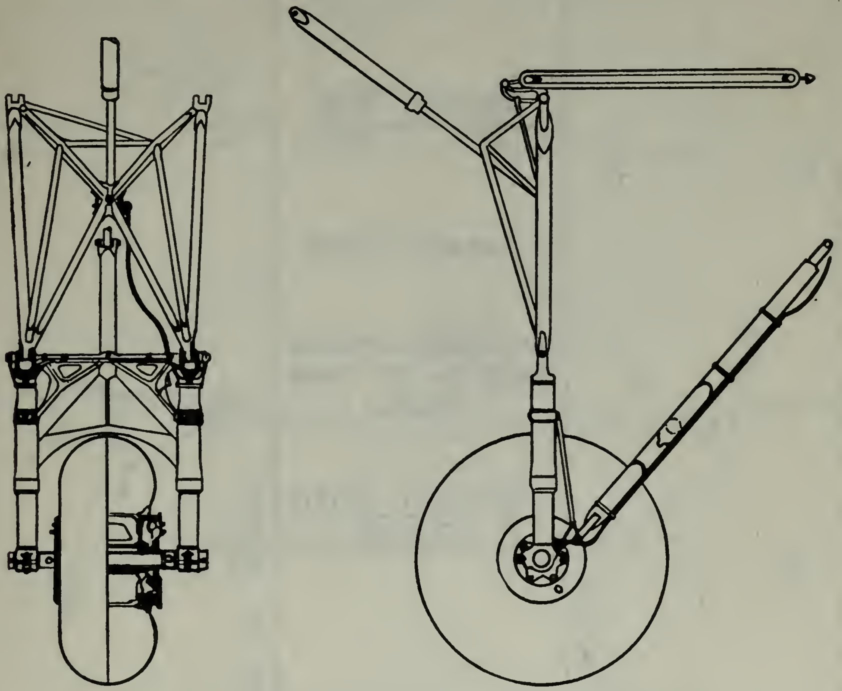
The simplest type of gear is that which has a conventional straight axle with the wheels on the ends supported by struts and bracing wire and some means of absorbing shocks. This type is obsolete.

It has been superseded by a split-axle type forming two independent parts. Each half of the gear is composed of three major parts, the axle assembly, the shock absorbing strut assembly, and the rear strut assembly. In some cases the shock-absorbing unit is made rigid enough to omit side bracing struts.

The axle of the assembly generally attaches to the center of the fuselage or to a strut extending below the fuselage. The shock-absorbing unit attaches to the side of the fuselage or to the wing. The rear strut braces the axle assembly to a point in back of the shock absorbing attachment.

Another more modern type is the cantilever single-strut landing gear. It consists of a single strut incorporating the shock absorbing unit attached either to the fuselage or wing. Longitudinal or transverse forces are resisted by small auxiliary struts situated near the main strut attachment point.

Mechanisms and methods used to retract landing gear are many and varied. To retract landing gear on an amphibian presents an entirely different problem than that on a conventional landplane because it must be folded into the hull of the plane. This involves complicated systems of levers, gears, or universals. Retractable landing gear on a low wing monoplane on the other hand, might involve only a single gear to fold the wheel into the wing. Most retractable landing gear mechanisms involve mechanically or hydraulically operated struts that fold wheels into the plane. Suitable locking devices for up and down positions are provided as are auxiliary controls to operate the gear in case of failure of the main controls. (See fig. 71.)



RETRACTABLE LANDING GEAR MECHANISM

Figure 71.

Another entirely different type is the stable landing gear, commonly called the tricycle landing gear, consisting of a single front wheel and two rear wheels. With this type the center of gravity of the ship is ahead of the rear wheels. Brakes are fitted only on the rear wheels, the front wheel being steerable and provided with a stable castering arrangement. This type of gear offers excellent directional stability in a landing. Full brakes may be applied locking the rear wheels without "nosing over."

With this gear, drift landings, i. e., cross-wind landings, give no difficulty. Figure 72 illustrates a landing with stable and conventional types of gear assuming that no air controls are used after the wheels contact the ground.

Figure 73 illustrates various types and designs of landplane landing gear, including the stable gear.

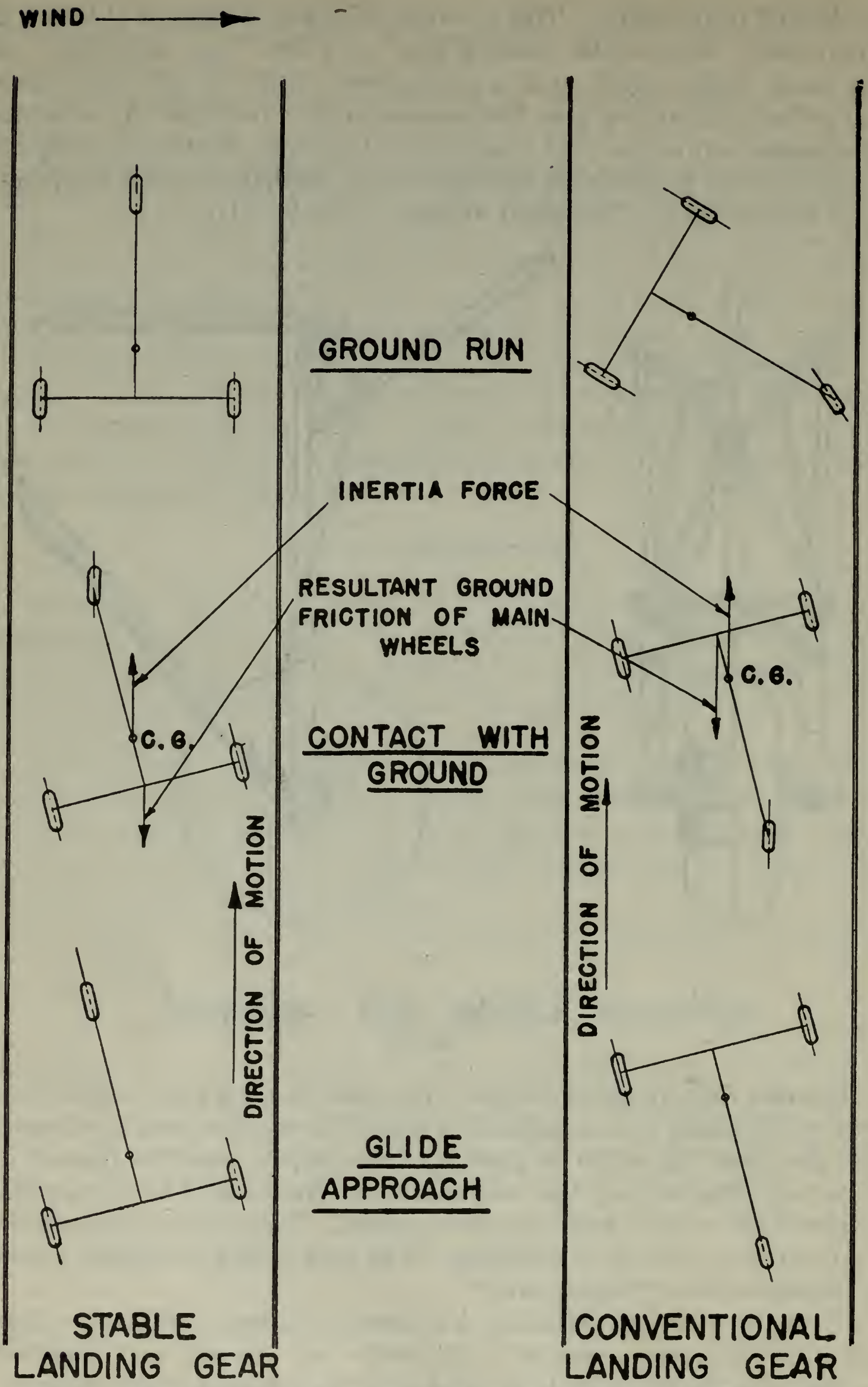
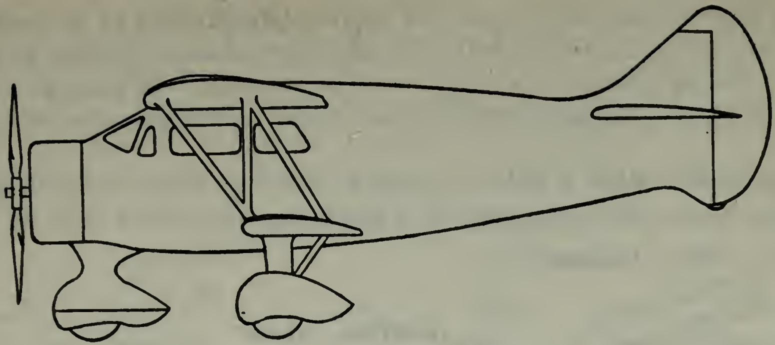
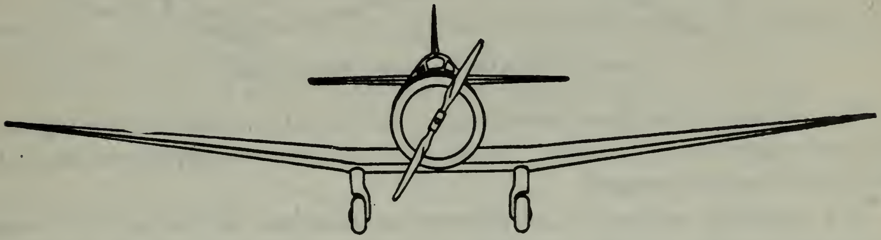


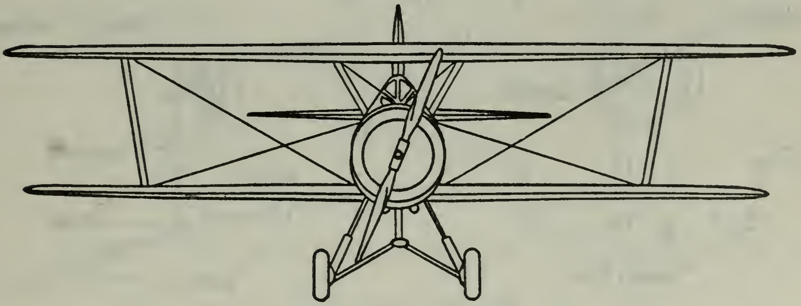
Figure 72.—Comparison between stable and conventional type landing gears during cross-wind landings.



STABLE (TRI-CYCLE)



CANTILEVER (SINGLE STRUT)



SPLIT AXLE

Figure 73.—Landing gear types.

## THE CONTROLS

*Types of controls.*—The control and stabilizing surfaces are operated by systems requiring separate design, and for each system a limited number of types are available from which to select.

For the ailerons, three types of control are feasible: (*a*) Cables and pulleys, (*b*) push and pull rods, and (*c*) torque tubes.

The *stick* method of operation is applicable regardless of the system employed, but, where the wheel or Deperdussin method is used, cables and pulleys are used, though push-and-pull rods may be operated. In general, stick control is found on comparatively light airplanes and wheel control on larger airplanes.

The *elevator control* is either a rocking beam and cable or a push-and-pull-rod system and is the same whether a wheel or stick control is used.

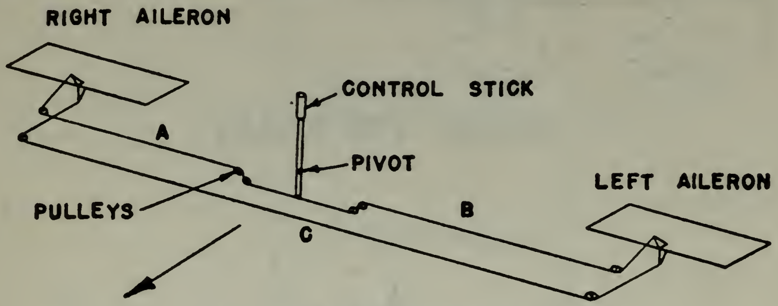


Figure 74.—Stick cable pulley-type aileron control.

The *rudder control* is almost always a cable system, directly joining rudder horns and rudder bar or pedals. Pulleys are omitted wherever possible in both rudder and elevator control.

The *stabilizer control* or adjustment mechanism is almost universally a nut attached to the fuselage capable of rotation from the cockpit by means of chain or cable. This nut actuates a worm on a tube paralleling the tail post and free to move axially. At the upper extremity of the tube is the fitting for attachment of the moving part of the surface.

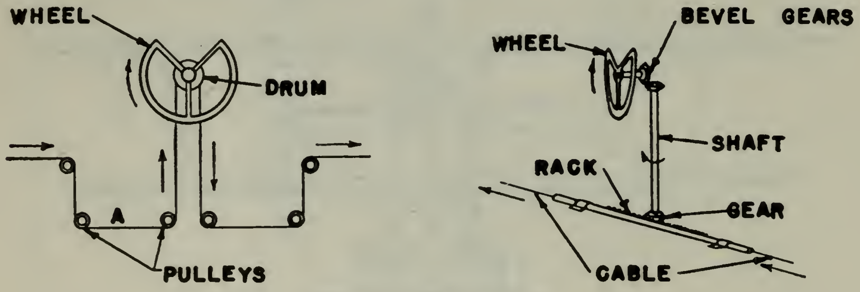


Figure 75.—Wheel controls.

*Aileron control.*—A schematic sketch of stick, cable, and pulley aileron control is shown in figure 74. Moving the control stick toward the right aileron moves the cable attachment toward the left since the stick moves about the pivot. This puts tension on cable A, and slacks off cable B. The right aileron is pulled up and, in moving up, pulls on the aileron balance wire C. The left aileron is thus pulled down. (Actually there will be no slack in cable B, for the system always is designed so that the cable lengths will be the same for all positions of the stick and ailerons.) Such a position of the ailerons generally will make the airplane bank to the right.

The expression *dep* for wheel operation is an abbreviation for Deperdussin who invented the system. When the wheel actuates the cables, as shown in figure 75, these are brought over pulleys to a drum attached to the wheel, and are so wrapped on the drum that when the wheel is turned to the right a pull is put on cable A, and the action is then the same as that illustrated.

Sometimes, particularly on large airplanes, it is advisable even though weight is added to use a system of geared rods in place of pulleys. The wheel is then geared to a shaft which is in turn geared to a rod sliding sideways in bearings. The cables are attached to the end of this rod, giving the same action as described previously.

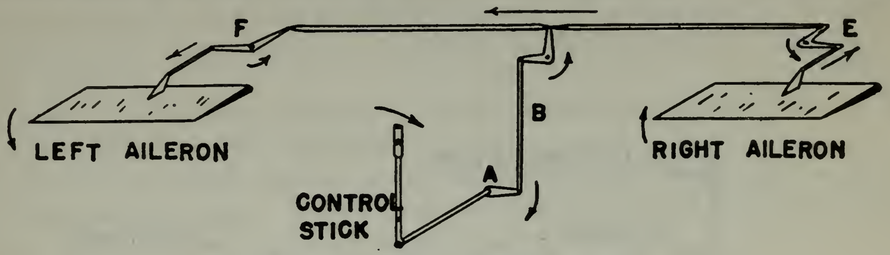


Figure 76.—Push pull rod type aileron control.

Figure 76 shows a *push and pull rod* system of aileron control.

The stick is attached rigidly to the lever A, through a torque tube. Moving the stick to the right moves lever A down, pulls down rod B, and moves bell crank C, which is mounted in a vertical plane. This moves rod D to the left, turns the bell cranks E and F as indicated by the arrows, thus pulling the right aileron up and the left aileron down. The airplane generally will bank to the right as required. Such a system, except for small airplanes, is heavy and not often used.

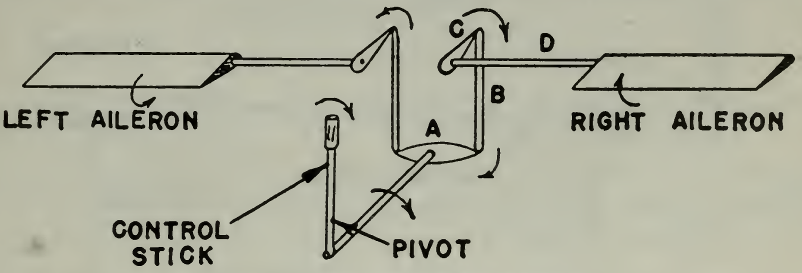


Figure 77.—Torque tube type aileron control.

The *torque tube* system of aileron control is shown in figure 77.

The stick, when moved to the right, turns arm A in the direction indicated, pulling rod B down, and through crank C, which is rigidly attached to tube D, moves the right aileron up. By the same motion the left aileron is moved down banking the airplane to the right. This control is much heavier than the wire and pulley system. However, it makes a rigid system and is used quite extensively on small airplanes. It is not adaptable for use on large airplanes, where long tubes must be used, for these tend to twist under load.

*Elevator control.*—Figure 78 (A) shows the usual elevator control employing a cable and walking beam system.

Pulling the stick back pushes rod B, and moves arm C (which is connected rigidly to cross tube D, and to which the walking beam E is connected), in the

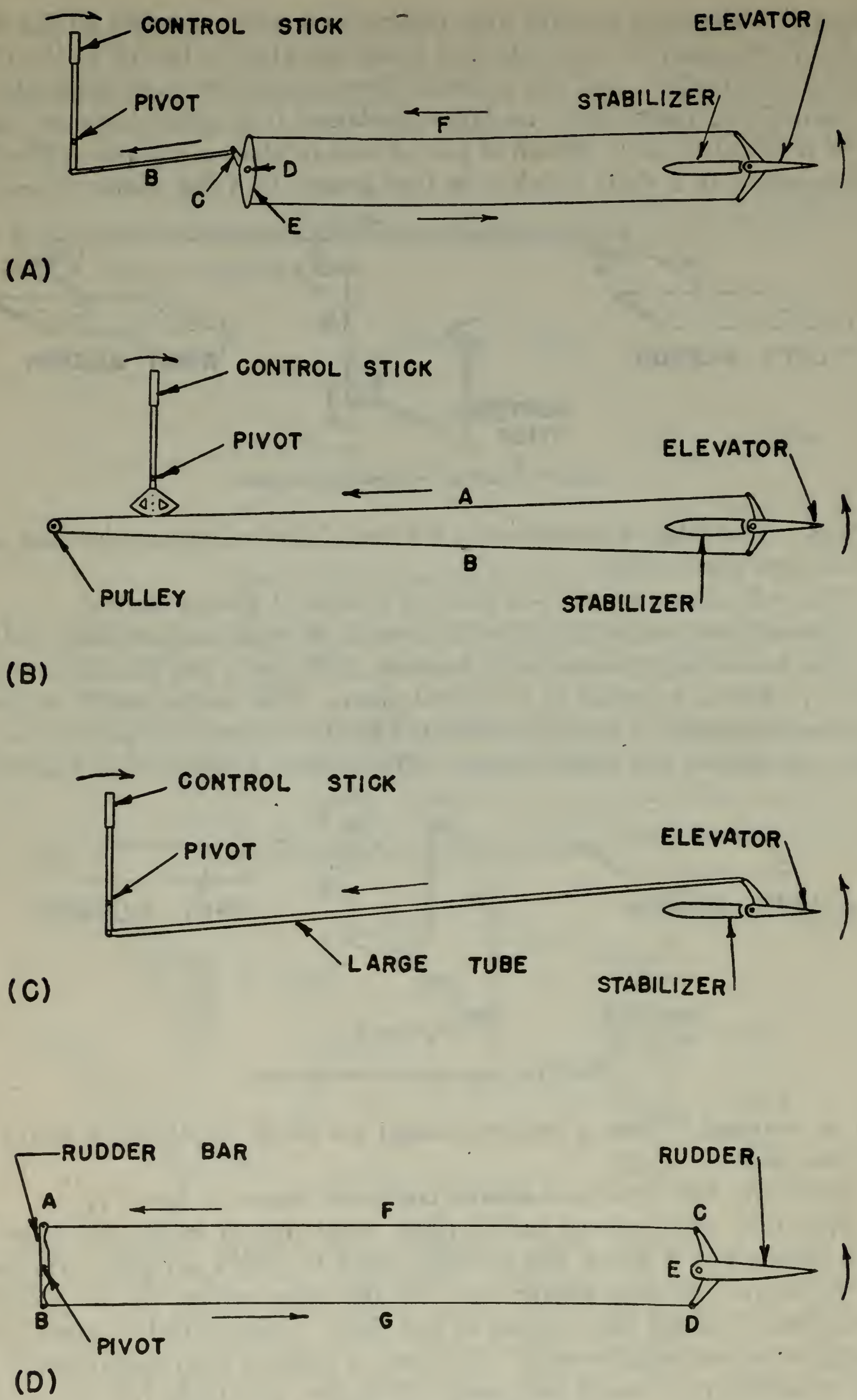


Figure 78.—Types of elevator control.

direction indicated. This puts a pull on cable F, which moves the elevator up as indicated. Sometimes the walking beam can be attached directly to the stick by means of a tube at the point marked *Pivot,* in which case the cables will be crossed to give the proper elevator movement. The dotted lines in the sketch show how a dual control stick would be connected to the mechanism. The mechanism shown is also used with *dep* control.

A modification of the *walking-beam* system, in which the wires from the elevator are connected to a quadrant on the bottom of the stick, and one wire led over a pulley forward of the stick, is illustrated in figure 78 (B). Pulling back on the stick pulls cable A, at the same time slacking-off on cable B, which passes over the pulley, and the elevator is raised.

The push and pull rod system, as applied to elevator control, is indicated in figure 78 (C).

*Rudder control.*—The conventional type of rudder control is shown in figure 78 (D), which is self-explanatory.

It should be noted in such a system, that points A and B and the pivot must lie in a straight line. This is true also of the points C, D, and E; and points C and D must be the same distance apart as A and B.

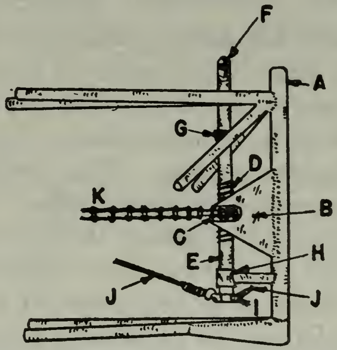


Figure 79.—Stabilizer adjustment mechanism.

A push-and-pull rod system is little used for the rudder control since it is heavier and more complicated.

*Adjustable stabilizer.*—The adjusting mechanism common with stabilizers ordinarily is operated by a system of sprocket gears and chains located in the pilot's cockpit and actuated by handwheel or ratchet lever which goes back through the fuselage to the stabilizer.

A typical stabilizer adjustment mechanism is illustrated in figure 79.

The tailpost, A, has a bracket, B, welded to it, which carries a sprocket, C. This sprocket actuates the worm, D, which is an integral part of the stabilizer adjustment post, E. The forked fitting, F, at the upper extremity of E, engages the fitting on the stabilizer spar insuring vertical displacement of the latter as the worm is rotated. Collars G and H maintain E parallel to A.

The fitting, I, at the lower extremity of E has lugs for the terminal clevises of the stabilizer brace wires, J. From the sprocket chain, K, wires lead to the cockpit (being wrapped around a drum) or another chain and sprocket which is operated by a handwheel. Forward rotation or *rolling* of the handwheel causes rotation of the sprocket, C, such as to lower the post, E, and vice versa.

*Auxiliary controls.*—Auxiliary controls are the trimming devices on the trailing edges of the elevator, rudder, and ailerons. Landing flaps on the trailing edges of lower wing panels also are considered as auxiliary or secondary controls.

Controls for the trimming devices are located in the cockpit for the pilot's operation. They may consist of a vertical handwheel on the left side of the cockpit the rotation of which actuates the elevator tabs, a small horizontal handwheel on the left side that actuates the rudder tab, and another that actuates the aileron tab. A crank on the right side actuates the landing flaps.

The actual mechanism operates as follows: Rotating the handwheel control winds the cables on a drum and causes rotation of flexible shafts at the after end of the fuselage or at the aileron which rotate screws connected to the tab beams, pushing them back and forth as desired.

Operation of the landing flaps mechanism is as follows: A series of chain and sprocket drives connect the hand crank to a torque tube that extends out into the lower wing panels. The torque tube terminates in gear boxes, *miter* gears within the boxes rotating screws that push the flaps up or down.

## FINAL ASSEMBLY SEQUENCE

The following discussion has been applied directly to the *biplane* type of airplane. In the last few years the number of monoplanes used for student instruction has increased greatly but it is considered unnecessary to discuss the rigging of a monoplane, because in most features this rigging will be the same as for the biplane, though much simpler. The cantilever monoplane generally has no rigging adjustments except for aileron tabs. The semicantilever monoplane is rigged by adjusting the length of the interplane struts in much the same way as the brace wires of a biplane are adjusted.

The assembly and alinement of the principal units of the airplane have been discussed, as were certain of the installation requirements. The sequence with which final assembly is undertaken will vary somewhat with the type of airplane, also with the type of building and handling equipment, but in most cases is as follows: After alinement, the fuselage first is covered, then engine mount and tail surfaces are installed and trued up. Simultaneously, fixed equipment and useful load items are positioned, for a great deal of work is involved therein. The engine next is mounted and powerplant items installed. Then comes the alinement of the center section, followed by the remainder of the wing cell. Finally, the landing gear is attached and its alinement checked.

### CENTER SECTION ALINEMENT

With the fuselage leveled the center section is first rigged to insure symmetry, correct stagger, and incidence. Steadiness of the fuselage on its horses, or platform, must be assured by tie-offs or blocking.

In rigging the center section the struts, if not adjustable, fall into place and are secured. If adjustable, they are attached to the fuselage and center section fittings, but the terminal adjustments are not locked. Thereafter the crossbar wires and stagger wires, if used, are installed and the panel centrally located by adjustment of the cross braces as shown in figure 80. Symmetrical location may be determined by dropping plumb lines A from corresponding wing hinge bolts B and correcting until the horizontal distance from the line A to the fuselage is the same on each side.

It also may be checked by driving a tack in the middle of the leading edge of the panel and dropping a plumb line C therefrom. The bob must split the centerline of the fuselage. Following this adjustment the tension in the cross braces D and C should be the same prior to safety wiring the turnbuckles or setting up the tie-rod lock nuts.

The stagger is measured by hanging plumb lines A (see fig. 80) from the eading edge of the center section just clear of the longerons and measuring the horizontal distance Z from the bob to the center of the lower wing hinge fitting B as indicated. This distance Z on each side should be equal to the designed stagger X plus the distance Y from the leading edge of the lower wing to the center of its hinge fitting. Where stagger wires are employed these are adjusted to give the desired dimension, or if adjustable struts are employed the terminal length is varied to insure the same.

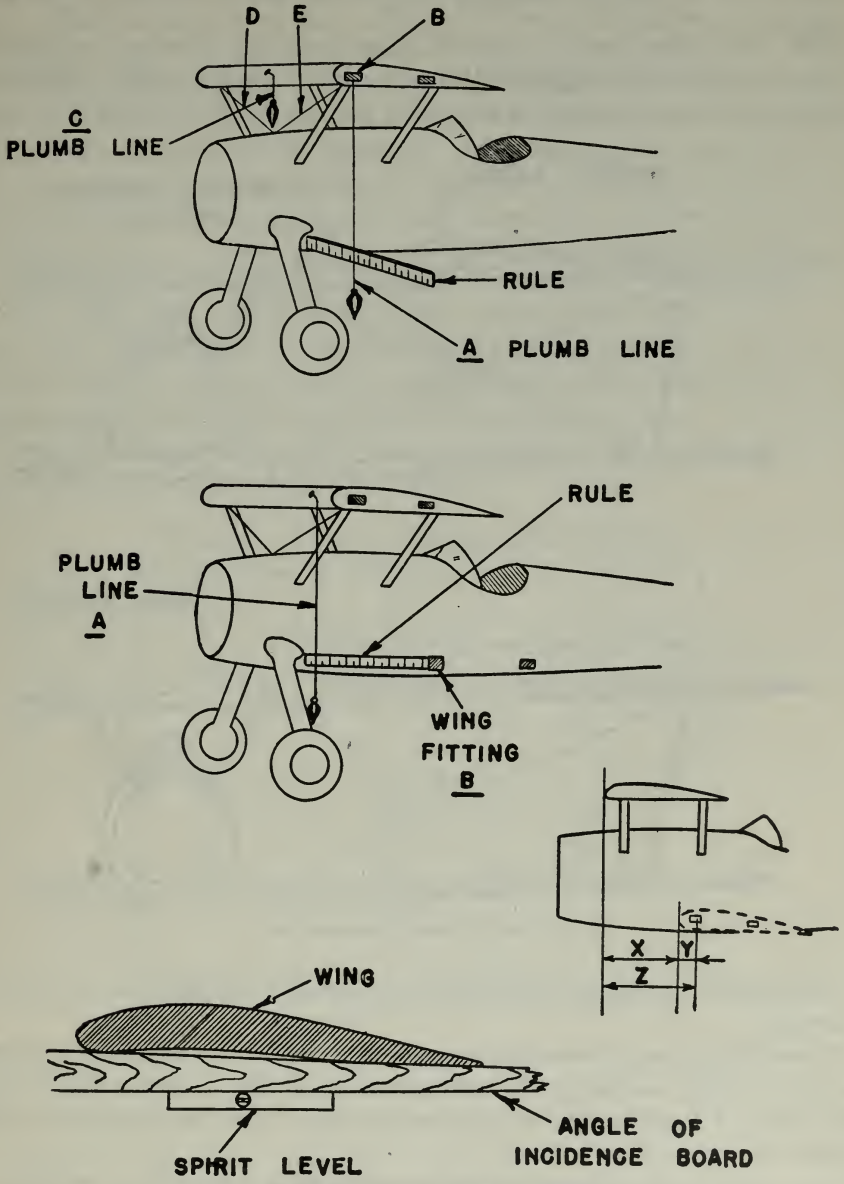


Figure 80.—Alinement measurements.

The angle of incidence is checked simultaneously, using the angle of incidence board and a spirit level, as shown. The proper alinement of the center section is of utmost importance, for thereon depends the adjustment of the entire wing cell.

## ALINEMENT OF WINGS

With the center section properly alined and the fuselage rechecked for level, the next step is the rigging of the remainder of the wing cell. This involves installation of the panels and so adjusting the interplane bracing as to produce the correct dihedral, stagger, incidence, sweepback, etc., specified by the erection instructions.

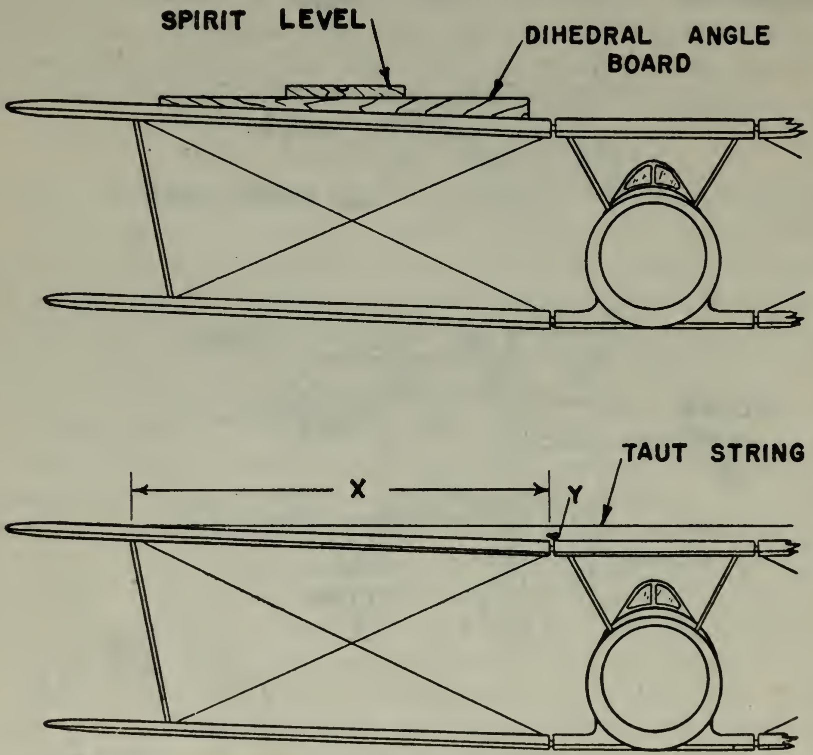


Figure 81.—Dihedral measurement.

Where the cell is of two or more bays, right and left wings can be assembled separately in jigs and attached subsequently to the center section. This is feasible since a rigid structure is afforded which may be transferred without collapse.

The employment of rigging jigs is particularly valuable in quantity production since time is saved.

In the usual single bay structure a jig still may be used for installing interplane struts and wires and adjusting them to approximately correct length. Otherwise, the panels may be supported on their leading edges for preliminary rigging as indicated and thereafter lifted as a unit to position on the airplane.

*Dihedral adjustment.*—The first adjustment to be made after rigging the wings is to insure the proper dihedral angle. A slightly excessive dihedral is produced initially by tensioning the landing wires. Later tensioning of the flying wires will decrease this angle, the desired value being obtained thereafter by minor correction of tensions. Two common methods of determining the dihedral angle are noted below in order of importance.

The first method employs an angle board and spirit level or bubble protractor. Some variation attends different types of interplane bracing, but, assuming the most flexible arrangement of flying and landing wires of both spars in the plane, the angle board is placed parallel to the front spar, and, keeping the flying and stagger wires loose, the landing wires are adjusted until the bubble of the spirit level is centered. Since the angle board has a straight edge it is easy to check the straightness of the spar by glancing beneath the board occasionally. After alinement of the front spar, the rear spar is trued-up in the same manner. Thereafter, the flying wires are tensioned and tested for equal tautness by striking with the heel of the hand or snapping with the fingers, and noting the vibration or sound. See figure 81 for method.

If a good angle board is not available, the string method may be used. A string is stretched taut across the upper wings to the wing tips or to points an equal distance from the center-line of the center section. The dihedral is then checked by measurement in inches as shown in the accompanying table covering the customary range for the angle.

TABLE FOR LATERAL DIHEDRAL

| Degrees | X Inches distance from point of support to end of spar | Y Inches distance from end of spar vertically up to the horizontal string |
|---|---|---|
| 0 | 100 | 0 |
| 1 | 100 | 1¾ |
| 2 | 100 | 3½ |
| 3 | 100 | 5¼ |
| 4 | 100 | 7 |
| 5 | 100 | $8\frac{11}{16}$ |

[Similar increases for greater angular incidence]

The distance X need not be 100 inches, as given in the table, but since X and Y increase in the same proportion, this is very simple. For example, the distance X (convenient to measure) on a biplane having a 3° dihedral angle may be 12 feet, 6 inches, or 150 inches, which is 1½ times 100 inches. The table gives Y equal to 5¼ inches for 3°. The X is 1½ times the Y given in the table, or 7⅞ inches. This is the proper distance up to the string when the wing has the correct lateral dihedral.

*Stagger and incidence adjustment.*—The desired dihedral angle having been obtained, stagger and incidence are adjusted simultaneously. This is due to the fact that a change in one will probably affect the other. Thus, lengthening the adjustable strut may decrease the stagger, but at the same time it decreases the angle of incidence. Again, tensioning both the forward landing wires and the rear flying wires increases the angle of incidence but simultaneously these adjustments affect the stagger. It is a question of give and take, slacking one wire, tightening another, and varying strut length until the correct stagger and angle of incidence are made on both wings.

*Wing heaviness* may be corrected by bending the aileron tab if one is available. The aileron tab is bent opposite to the direction the aileron should move to correct the wing heaviness. If this means of correcting is not available the angle of incidence of the heavy wing may be increased toward the wing tip by altering the length of the interplane struts and the rear landing and flying wires so as to pull the trailing edge down—called *wash-in.*

If a small amount of wash-in is not enough to correct wing heaviness, *wash-out* may be rigged into the light wing in the same way as washing-in the heavy wing except that the trailing edge is raised. If excessive adjustments are required the plane should be checked and may require complete rerigging.

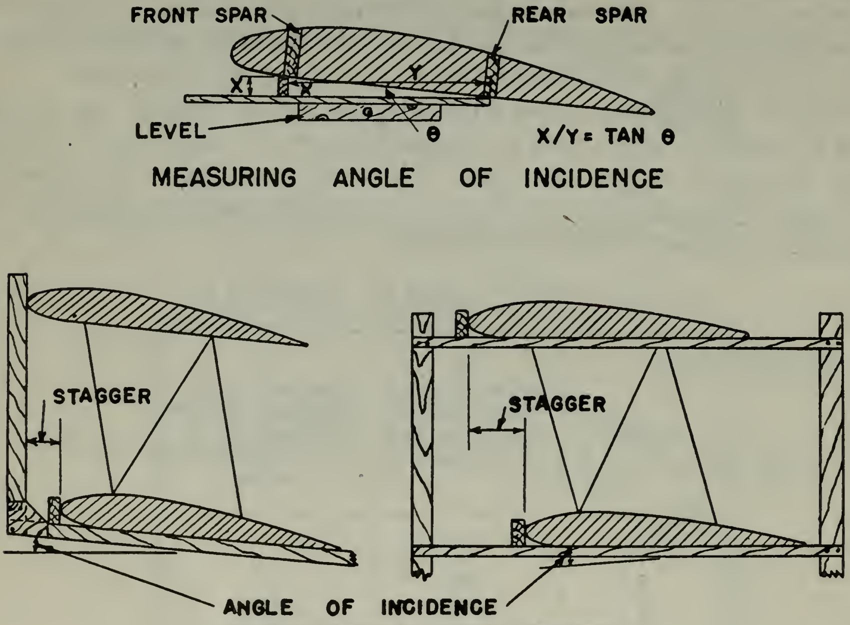


Figure 82.—Stagger and incidence measurement.

If the plane has a *tendency to yaw* to the right or left when the feet are removed from the rudder bar at cruising speed the rudder tab, if one is used, should be bent to correct this error. In some cases where there are no rudder tabs the vertical fin may be off-set to compensate for this error.

Stagger may be measured outboard in the same manner as for the center section. The angle of incidence at the wing roots is fixed by the fittings on the fuselage and center section. It is necessary then merely to insure this angle throughout the spar. This is done by means of an *angle of incidence board* of correct angle and a spirit level. If no angle of incidence board is available, a straight edge may be used, placing one corner thereof beneath and against the center of the rear spar, holding it in line with the ribs, and leveling it with a spirit level. The vertical from the center of the bottom of the front spar to the straight edge is then measured and therefrom the angle is determined as indicated.

## RIGGING AFTER FLIGHT CHECK

After flight test it may be necessary to alter the rigging of a plane in order to make it fly *hands off.* Rigging faults may be wing heaviness, tendency to yaw, vibration or flutter, or ground looping. These faults may be corrected in most cases by minor alterations of the rigging.

*Vibration and flutter* may be caused by improper rigging of the controls and by looseness in landing and flying wires or else by the engine. In the event that flutter occurs without engine vibration the ship should be checked over carefully to make sure that the control systems, cowlings and fairings, and bracing wires are properly secured. Flutter also may be caused by excessively high or low speeds during flight and generally no rigging fault is indicated by this flutter. High speed flutter may be very dangerous so a plane should not be operated at speeds above those mentioned in the placard.

If an airplane shows an abnormal tendency to *ground loop* when landing or taxing, the rigging of the landing gear should be rechecked. Frequently slight misalinement of the tail wheel will cause decided ground looping tendency.

During the flight test the position of the stabilizer adjustment should be noted. If this adjustment is an appreciable amount away from neutral or if the airplane shows difficult in handling during flight or landing, a check should be made of the load distribution to determine that the center of gravity is within the limits permitted.

## ALINEMENT BY SIGHT

Alinement by sight is a useful method as a final check on symmetry of the airplane with particular adaptation to: (*a*) Equal angles of incidence of wing panels and center section; (*b*) parallelism of stabilizer and wing axes; (*c*) plumbness of rudders and fins; (*d*) parallelism of upper and lower wings.

"Sighting out of wind" is an old shipbuilding term relating to the determination by sight that a series of lines are in the same plane. The method is exemplified by sighting a fuselage with level upper longerons, specifically noticing the appearance of the lined-up fuselage as viewed from behind the tailpost with the eye on the line of the upper longerons, then the appearance when the eye is slightly raised. The upper crosswise struts should be exactly parallel. Should this not be the case, the fuselage is not in proper alinement.

Sighting for undeviating angle of incidence is done by taking a position ahead or behind the airplane in the plane of symmetry and at such a height that the lower surface of a wing panel can just be seen. Shutting one eye, the other is used to note the lower surface near the tip. It then is raised until the surface is no longer seen, or winks out of sight. If properly alined, this winking will occur with the same lift of the eye throughout the panel under examination and symmetrical locations will give the same appearance. The lighting must be uniform if optical illusions are to be avoided and if no confusion with objects in the background is to exist.

To check parallelism of the stabilizer and wing axes, the elevator is dropped so that the top surface of the stabilizer may be brought into line with upper or lower wings as viewed from the rear. Nonparallelism is immediately discerned.

Rudder and fin may be checked for being vertical by noting their parallelism to the tailpost or their projection on some strut, fitting, or other point known to be in the plane of symmetry. If the stabilizer spar is horizontal, unequal angles between it and the vertical surfaces will be visible, as indicated, if these latter are "out of wind."

Parallelism of the leading edges of the wings is determined by sighting the upper wing "out of wind" from a position beneath the leading edge of the lower wing.

Each type of airplane presents some minor faults in erection plans. These must be rectified and new methods adopted which will insure correct rigging with the smallest possible delay. Many shops adopt a "trial and error" method until the correct solution is found; this then becomes standard with the shop.

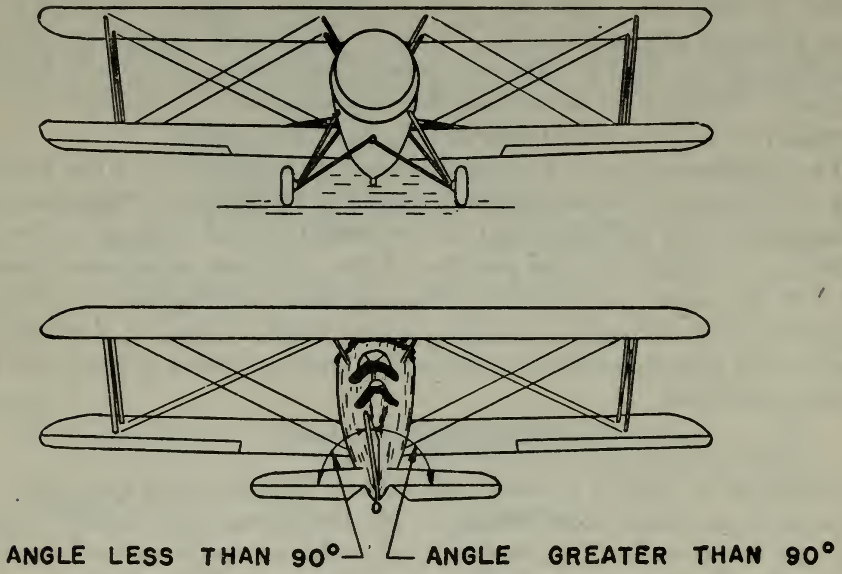


Figure 83.—Alinement by sight.

With the later type all-metal planes, little rigging or changing can be done. This is due to the use of jigs in the assembly of all the parts which are designed to fit each other with practically no adjustment. There are a few types with slight adjustment in the wing hinge fittings to increase or decrease the angle of incidence of the wings. Generally, lateral, longitudinal, and directional balance is cared for by the use of adjustable control tabs on the control surfaces, also called trimming tabs.

### LANDING GEAR ALINEMENT

The landing gears of modern landplanes are self-alining since they are jig assembled and rarely have wire braces. With seaplanes this is not the case, cross braces being employed both fore and aft and athwartships as indicated. The proper fore and aft location of the seaplane's float system is of vital importance for the float weight must be centered correctly with respect to the center of gravity of the ship and the step of the float must be located exactly in its proper position.

The first step after installing the float is to adjust and tram the athwartship cross braces so that the float is located centrally. Thereafter, the fore and aft location is fixed by the horizontal distance of fittings, step, or other float reference point from the propeller hub, leading edge of the lower wing, or other body reference point. Strut lengths or wire braces are varied to insure the proper longitudinal position. Finally, the lock nuts are jammed on the struts and tie rods and turnbuckles, if used, are safetied when proper tensions are assured.

When seaplane rudders are part of the equipment, care must be exercised in proper installation, otherwise serious damage probably will be the result.

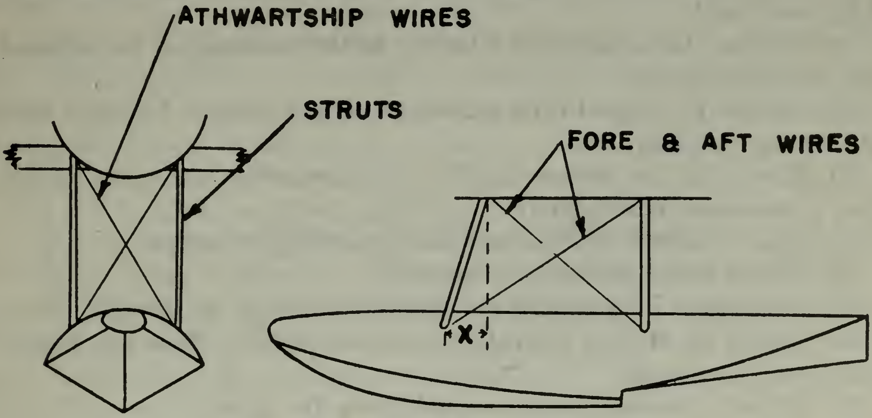


Figure 84.—Float alinement.

## *Questions*

1. List 5 subassemblies of an airplane.
2. Why is an assembly jig often used?
3. What is alinement?
4. Why is alinement of a plane important?
5. Why is it sometimes necessary to rerig a plane while it is in service?
6. What is the purpose of aileron tabs?
7. What is a jig?
8. What is the usual location of the center of gravity of an airplane?
9. Why is placement of wings about the center of gravity important?
10. What effect may result if the center of gravity is: (*a*) Located too far rearward? (*b*) Located too far forward?
11. Why is the two-spar wing structure desirable?
12. Sketch a two-spar wing structure. Name all of the parts.
13. What is an aileron spar?
14. Why is the root end rib made stronger than the rest?
15. What are advantages and disadvantages of the monospar type construction?
16. Describe the trammel method of checking internal wing alinement.
17. What is the distinctive feature of the full cantilever wing?
18. What is the distinctive feature of the semicantilever wing?
19. Would there be more load on the landing wire when a plane is flying inverted or when it is on the ground?
20. Distinguish between the Warren truss and the Pratt truss.
21. Which of the above trusses will maintain its shape better?

22. Which will be easier to rig?

23. Of what does the empennage consist?

24. Into what groups may the surfaces of the empennage be classified?

25. What is the advantage of an externally braced empennage as compared with the internally braced one?

26. Why is it necessary to fasten the two elevator control surfaces together?

27. What adjustments may be made on a cantilever monoplane so that it will fly *hands off?*

28. Outline the steps to be followed in the assembly of an airplane with which you are familiar.

29. Outline the steps in the alinement of an airplane of biplane type with which you are familiar.

30. How does the alinement of a semicantilever monoplane differ from that of a cantilever monoplane?

31. Make a sketch to illustrate the terminology of wings.

32. Where is the aileron spar located?

33. How many hinge points generally are used on an aileron?

34. Sketch an N-type interplane strut assembly. Show the parts which are adjustable in length.

35. Sketch a fuselage structure and name five parts.

36. Indicate on the sketch the members which will be under tension loading with a minus sign and compression loading with a plus sign when there is down load on the tail due to back stick pressure.

37. Compare the advantages of the Pratt and the Warren type truss for fuselage construction.

38. Explain how alinement is obtained in a Warren type truss fuselage during construction.

39. Name the parts which comprise the empennage.

40. How many stabilizers have a symmetrical airfoil shape?

41. Discuss the adjustment of cables for the proper alinement of the rudder.

42. Why will small low-powered airplanes generally use fixed type landing gear?

43. How may faulty rigging of ailerons be observed?

44. How is the adjustable stabilizer dispensed with in most modern airplanes?

45. Sketch the stabilizer adjustment linkage for an airplane with which you are familiar.

46. Why must an airplane be leveled up with the alinement if it is being checked by the use of bubble levels and plumb bobs?

47. Explain how propeller torque may be corrected in an airplane when additional correction is required to make it fly straight.

48. List causes of vibration and flutter.

49. Explain the principle of "sighting out of wind."

# CHAPTER VII.—MAINTENANCE AND CARE OF AIRPLANES

*Maintenance* is the term applied to the processes necessary for retention of the airplane structure, powerplant, equipment, and accessories in satisfactory condition for flight. The goal of maintenance is the preservation of material, insofar as possible, in the condition which obtained immediately after fabrication. This requires the prevention of deterioration as far as practicable. Deterioration, however, eventually will make inroads in spite of rigid maintenance, with the net result that the material no longer can be preserved economically in condition required for flight. The period of usefulness of such material is thus ended and it must be replaced.

The importance of maintenance cannot be overestimated. The airplane is a highly stressed structure, designed with a load factor dependent on the mission it is called upon to perform. Similarly, the airplane engine, with its low weight per horsepower, is dependent on rigid inspection and maintenance to insure efficient and dependable operation through reduction of deterioration to a minimum.

## PRIMARY MAINTENANCE FUNCTIONS

The primary maintenance functions are: (*a*) Inspection, (*b*) upkeep, (*c*) repair, and (*d*) overhaul.

*Inspection* involves examination of the structure, powerplant, and fixed equipment as a check on the integrity and functioning thereof.

*Upkeep* embraces the normal care of the airplane and the routine processes of cleaning, corrosion prevention, maintenance of alinement, and adjustment of clearance.

*Repair* covers the routine operations of mending and renewal of parts which can be accomplished by the certificated mechanic.

*Overhaul* comprises complete disassembly, repair or replacement of parts, reassembly, and test.

Each of the primary maintenance functions are discussed in this chapter except overhaul. This subject is considered beyond the scope of the controlled pilot training course for which this text has been prepared.

The airplane is subject to the same deteriorating influences as are other mechanical contrivances, i. e., (*a*) abuse in operation; (*b*) detrimental effects of climatic conditions; and (*c*) normal wear in use.

*Operation abuse* covers all unethical handling of the powerplant, structure, and equipment including racing, overheating and uneven cooling of the engine, improper maneuvering of the airplane from consideration of stresses for which designed, and manhandling of delicate instruments and accessories. Heat, cold, sunlight, and moisture are the principal atmospheric influences producing corrosion and decay of material and warping of structures. Finally, while material will fail as a result of poor design or faulty construction to which shock, fatigue, or wear have contributed, these latter, of themselves, also cause material deterioration in service.

## INSPECTION

Operating inspections serve as the safeguard against these influences of deterioration. By inspection alone are incipient failures discovered and any carelessness and oversights of maintenance crews disclosed. A frayed control here, a turnbuckle without safety wire there, or any of a hundred things that constitute potential crashes, may be brought to light.

Offhand it would appear that the only safe and sensible thing to do would be to inspect completely the airplane before every flight. This would certainly insure minimum possibility of any failure occurring during subsequent operation, but at the same time such operation would occur all too infrequently owing to the time required for thorough examination.

Experience, fortunately, shows that certain parts of the airplane suffer little, if any, deterioration over a fairly extensive number of flying hours. Other parts are liable to deteriorating influences over shorter periods. Consequently, experience, combined with good judgment, makes possible the segregation of items which should be inspected at definite intervals from those which should receive daily attention as well as those which should be examined before each flight. Inspection time thus can be cut from what would obtain if complete inspection were to be made prior to each flight.

The individual pilot, however, is, and must always be, responsible for the aircraft which he is about to fly. He therefore not only must satisfy himself that the above inspection has been performed properly, but he should make his own inspection.

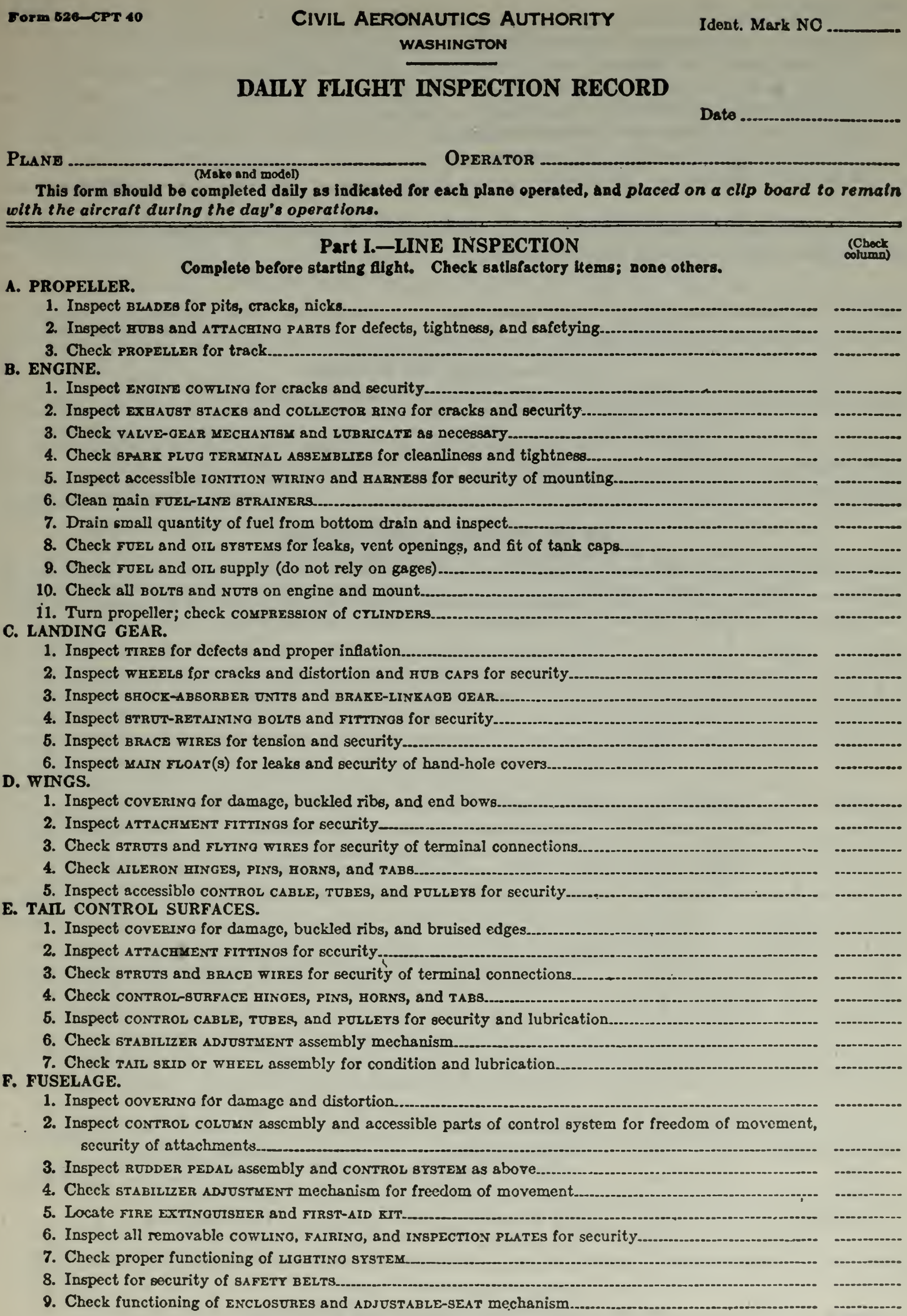
The fact that the airplane previously has been examined by inspection personnel, in compliance with daily inspection routine, or has been flown since inspection, in nowise relieves the pilot of responsibility. However, good judgment may govern the scope of this inspection to fit the situation.

The Civil Aeronautics Administration has developed a record form which operators participating in the pilot training program must keep on each of their ships used for instruction. This form, known as the DAILY FLIGHT INSPECTION RECORD, makes provisions for a line inspection, a servicing record, and a report after each flight. The form is shown in figures 85 and 86.

The principal factors which may modify exact duplication of the DAILY FLIGHT INSPECTION RECORD by the pilot are summarized below:

1. Character of inspection personnel.
2. Thoroughness demanded and checks made by operations manager or flight superintendent on such personnel.
3. Adequacy or shortage of airplanes and personnel.
4. Hours flown by the airplane since last complete check.
5. Hours flown by the airplane since new or major overhaul.
6. Work performed on the airplane since last flight.
7. Pilot's report after previous flight.

Where it is known that the inspection personnel are thorough and painstaking, as evidenced by high morale, careful training, and consistently efficient work, real reliance may be placed on a daily flight inspection



Form 526—CPT 40

CIVIL AERONAUTICS AUTHORITY
WASHINGTON

Ident. Mark NC ..........

## DAILY FLIGHT INSPECTION RECORD

Date ..........................

PLANE .......................................... (Make and model) OPERATOR ..........................................

**This form should be completed daily as indicated for each plane operated, and *placed on a clip board to remain with the aircraft during the day's operations.***

### Part I.—LINE INSPECTION

(Check column)

**Complete before starting flight. Check satisfactory items; none others.**

**A. PROPELLER.**

1. Inspect BLADES for pits, cracks, nicks ..........
2. Inspect HUBS and ATTACHING PARTS for defects, tightness, and safetying ..........
3. Check PROPELLER for track ..........

**B. ENGINE.**

1. Inspect ENGINE COWLING for cracks and security ..........
2. Inspect EXHAUST STACKS and COLLECTOR RING for cracks and security ..........
3. Check VALVE-GEAR MECHANISM and LUBRICATE as necessary ..........
4. Check SPARK PLUG TERMINAL ASSEMBLIES for cleanliness and tightness ..........
5. Inspect accessible IGNITION WIRING and HARNESS for security of mounting ..........
6. Clean main FUEL-LINE STRAINERS ..........
7. Drain small quantity of fuel from bottom drain and inspect ..........
8. Check FUEL and OIL SYSTEMS for leaks, vent openings, and fit of tank caps ..........
9. Check FUEL and OIL supply (do not rely on gages) ..........
10. Check all BOLTS and NUTS on engine and mount ..........
11. Turn propeller; check COMPRESSION of CYLINDERS ..........

**C. LANDING GEAR.**

1. Inspect TIRES for defects and proper inflation ..........
2. Inspect WHEELS for cracks and distortion and HUB CAPS for security ..........
3. Inspect SHOCK-ABSORBER UNITS and BRAKE-LINKAGE GEAR ..........
4. Inspect STRUT-RETAINING BOLTS and FITTINGS for security ..........
5. Inspect BRACE WIRES for tension and security ..........
6. Inspect MAIN FLOAT(S) for leaks and security of hand-hole covers ..........

**D. WINGS.**

1. Inspect COVERING for damage, buckled ribs, and end bows ..........
2. Inspect ATTACHMENT FITTINGS for security ..........
3. Check STRUTS and FLYING WIRES for security of terminal connections ..........
4. Check AILERON HINGES, PINS, HORNS, and TABS ..........
5. Inspect accessible CONTROL CABLE, TUBES, and PULLEYS for security ..........

**E. TAIL CONTROL SURFACES.**

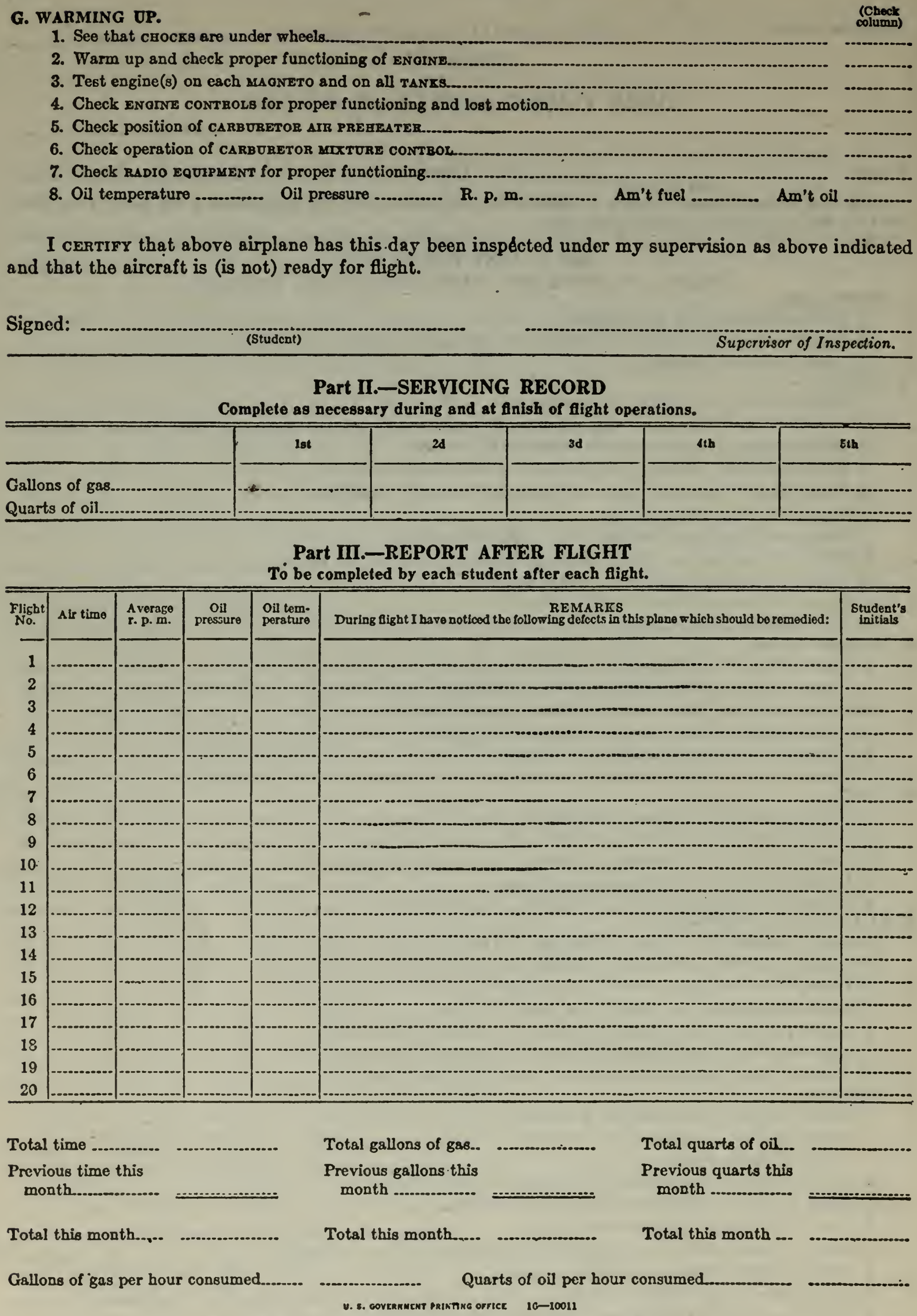
1. Inspect COVERING for damage, buckled ribs, and bruised edges ..........
2. Inspect ATTACHMENT FITTINGS for security ..........
3. Check STRUTS and BRACE WIRES for security of terminal connections ..........
4. Check CONTROL-SURFACE HINGES, PINS, HORNS, and TABS ..........
5. Inspect CONTROL CABLE, TUBES, and PULLEYS for security and lubrication ..........
6. Check STABILIZER ADJUSTMENT assembly mechanism ..........
7. Check TAIL SKID or WHEEL assembly for condition and lubrication ..........

**F. FUSELAGE.**

1. Inspect COVERING for damage and distortion ..........
2. Inspect CONTROL COLUMN assembly and accessible parts of control system for freedom of movement, security of attachments ..........
3. Inspect RUDDER PEDAL assembly and CONTROL SYSTEM as above ..........
4. Check STABILIZER ADJUSTMENT mechanism for freedom of movement ..........
5. Locate FIRE EXTINGUISHER and FIRST-AID KIT ..........
6. Inspect all removable COWLING, FAIRING, and INSPECTION PLATES for security ..........
7. Check proper functioning of LIGHTING SYSTEM ..........
8. Inspect for security of SAFETY BELTS ..........
9. Check functioning of ENCLOSURES and ADJUSTABLE-SEAT mechanism ..........

16—10011

Figure 85.—Daily flight inspection record form (front).



**G. WARMING UP.** (Check column)

1. See that CHOCKS are under wheels........ ..........
2. Warm up and check proper functioning of ENGINE........ ..........
3. Test engine(s) on each MAGNETO and on all TANKS........ ..........
4. Check ENGINE CONTROLS for proper functioning and lost motion........ ..........
5. Check position of CARBURETOR AIR PREHEATER........ ..........
6. Check operation of CARBURETOR MIXTURE CONTROL........ ..........
7. Check RADIO EQUIPMENT for proper functioning........ ..........
8. Oil temperature .......... Oil pressure .......... R. p. m. .......... Am't fuel .......... Am't oil ..........

I CERTIFY that above airplane has this day been inspected under my supervision as above indicated and that the aircraft is (is not) ready for flight.

Signed: .................................... (Student) .................................... *Supervisor of Inspection.*

## Part II.—SERVICING RECORD

**Complete as necessary during and at finish of flight operations.**

| | 1st | 2d | 3d | 4th | 5th |
|---|---|---|---|---|---|
| Gallons of gas........ | | | | | |
| Quarts of oil........ | | | | | |

## Part III.—REPORT AFTER FLIGHT

**To be completed by each student after each flight.**

| Flight No. | Air time | Average r. p. m. | Oil pressure | Oil temperature | REMARKS<br>During flight I have noticed the following defects in this plane which should be remedied: | Student's initials |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| 5 | | | | | | |
| 6 | | | | | | |
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| 14 | | | | | | |
| 15 | | | | | | |
| 16 | | | | | | |
| 17 | | | | | | |
| 18 | | | | | | |
| 19 | | | | | | |
| 20 | | | | | | |

Total time .......... ..........
Previous time this month.......... ..........
Total this month.......... ..........

Total gallons of gas.......... ..........
Previous gallons this month .......... ..........
Total this month.......... ..........

Total quarts of oil.......... ..........
Previous quarts this month .......... ..........
Total this month .......... ..........

Gallons of gas per hour consumed.......... ..........
Quarts of oil per hour consumed.......... ..........

U. S. GOVERNMENT PRINTING OFFICE 16—10011

Figure 86.—Daily flight inspection record form (back).

record properly filled out and signed. On the other hand, skepticism as to the thoroughness of inspection is justified where a shortage of airplanes and personnel exist, for then the inspection personnel will be pushed for time and may overlook certain faulty items. Again, the airplane but recently given a periodic inspection is much more apt to be in satisfactory condition than one about due for such a check. Furthermore, if any repairs, replacements, or adjustments have been made since the previous flight, these may have been made under pressure and without the requisite thoroughness dictating a careful examination of all such work. Finally, a pilot's report that "the airplane is satisfactory in all respects" might imply that the airplane requires no inspection whatsoever.

There are, however, too many cases on record of serious injuries and losses of life attributable to implicit dependence on others. Such dependence, combined with too little regard for the chances being taken, constitutes a menace to flying, especially where the personnel turnover is large.

Again, the individual pilot has experience to prove that oversights are quite common and that what appears to be satisfactory alinement or functioning of powerplant and controls to others as indicated by reports, may in truth be so unsatisfactory as to dictate the making of immediate repairs. Drain plugs now and then are not replaced in float bottoms prior to flight. Excessive vibration, due to loosened engine mounting hold-down bolts or propeller out of track, may be discovered only when the engine is opened wide to check for revolutions per minute on the ground. The pilot may find that, on cutting his switch, the engine continues to run. Controls, reported as functioning properly, may prove so stiff in operation as to indicate and suggest the location of binding on sheaves or tie rods.

The pilot is foolhardy, to say the least, who, in addition to insuring that his powerplant is functioning perfectly in all respects, does not make certain that the aircraft is equally airworthy. The experienced pilot in carrying out the daily flight inspection normally will determine the structural integrity of his entire aircraft while approaching it before a flight. The proper condition of such items as brace wires, fabric, tires, wheels, struts, empennage, and the security of all inspection plates, if not verified visually, should be determined individually. The proper loading of equipment and baggage, the security of all movable equipment, and the normal functioning of all controls, instruments, and other items of equipment must be verified. Visual inspection SHOULD reveal control battens or locks remaining in place; full movement of the controls will definitely reveal their presence. Yet fatal crashes have occurred due to the pilot having taken off with controls locked.

The inexperienced pilot should by detailed inspection of his aircraft before each flight develop the ability to make the more rapid but equally thorough inspection which every pilot must make, if he expects to continue his aviation career.

A 5-minute period or even 15 minutes devoted to the verification of structural integrity is excellent and cheap insurance against hours or days spent in the water or on a mountainside waiting rescue operations.

**The pilot's REPORT AFTER FLIGHT (see fig. 86), should constitute a complete summary of the condition and performance of the aircraft during the**

individual flight. The mere fact that an aircraft functioned during a flight in no wise guarantees its acceptability for further flight.

The primary factors which will dictate modification from the daily inspection, are:

1. Character of the previous flight.
2. Pilot's "Report after Flight."

The former involves many considerations, principal among which are:

1. Length of flight.
2. Ability of the pilot.
3. Purpose of the flight.
4. Conditions encountered during flight.

The greater the length of the flight, the more rigid should be the inspections undertaken. The more experienced the pilot the less will be the abuse given the airplane, and consequently, less inspection will be required. Training flights subject the airplane to perhaps the greatest abuse, while cross-country hops afford the least for equal duration. Adverse weather conditions encountered during flight may impair seriously the integrity of the airplane. In general, it may be said that flights involving sharp maneuvers operating at full throttle and repeated landings suggest much more inspection thereafter than those in which such operations are not involved. This, however, should not relieve the inspection and maintenance personnel from keeping a watch on airplanes in their vicinity. A rough landing in front of the hangar suggests many more at outlying fields, and the necessity for more than the usual thoroughness in inspection.

## UPKEEP

*Upkeep* is the term applied to those regularly repeated processes which are carried out on aircraft material to maintain it, insofar as possible, in its original condition; in other words, to prevent deterioration.

The four principal reasons for efficient upkeep are:

(*a*) The probability of material failure is minimized by maintaining parts and assemblies at their initial strength values.

(*b*) The material is preserved in a clean and shipshape condition, which is indispensable to inspection, morale, and organization in general.

(*c*) The operating life of the material is increased by preventing deterioration.

(*d*) Economy in operation is assured.

These reasons justify the effort required for proper upkeep of practically all mechanical contrivances. This is particularly the case with the airplane where life is at stake and the cost item no mean consideration.

It then remains to consider the more important processes peculiar to upkeep which should serve as a backbone for particular cases.

*Fabric surfaces.*—When practicable, fabric-covered surfaces should be washed down with fresh water and dried off if exposed to salt-water spray. At least once a week all surfaces should be washed with warm water heavy in soapsuds from castile soap. Soaps containing alkali are injurious and must not be used.

Surfaces which are badly oil-soaked are extremely hard if not impossible to clean by the above method. In such cases a rag soaked in clear, undoped gasoline may be used to remove the oil or grease. The surface then should be thoroughly washed with soapsuds and rinsed with fresh water.

When an airplane has been in service for some time, the wing fabric often loses its tautness and becomes dead, resulting in considerable loss of lift, as the wing contour no longer conforms to the most efficient airfoil section. The application of an additional coat of pigmented dope will alleviate somewhat this condition by restoring part of the original tautness.

The surface to be redoped should first be washed thoroughly and rinsed as outlined above, and doping should not commence until the surfaces are thoroughly dry. A clear, dry, sunshiny day should be selected, and a sufficient force of men employed to insure completion of the work in the early afternoon so that the surfaces will dry before nightfall. A coat of dope thinner sprayed on may be advantageous in softening the old dope before applying the additional new coat.

*Metallic structures.*—The vital consideration in upkeep of the metallic structure of the airplane is elimination of corrosion insofar as possible. The corrosive effects of water and moisture-laden atmosphere upon the usual airplane metals, particularly where these contain salts, are serious. The upkeep problem then resolves itself into prevention of moisture coming in contact with the bare metal and, where this has not been feasible, into elimination of corrosion prior to refinishing.

Corroded spots of aluminum alloy parts should be scraped or wire-brushed to good metal. The surfaces then should be rinsed with a cleaner. An acid solution, generally nitric or chromic acid, is used because it dissolves away the products of corrosion and removes any grease film, which may be present though not visible to the eye, and because it does not promote corrosion of the alloy as does a caustic solution. The acid is removed by rinsing with pure water and the surface then is finished in accordance with manufacturers' instructions or is given one coat of standard primer and two top coats of standard enamel.

Two of the major causes of corrosion of aluminum alloy, the material which is used most frequently in the airplane structure, are: First, defective heat treatment and second, imperfect insulation of aluminum alloy from dissimilar metals. Defective heat treatment is not apparent to the eye and results in a predisposition of the metal to intercrystalline corrosion. This is largely a manufacturing problem and is being met by mechanically automatic temperature controllers for heat-treating furnaces and baths. The use of unheat-treated or poorly heat-treated aluminum alloy parts in repair work is poor practice. Design specifications call for the use of similar metals wherever practicable, otherwise adequate insulation between the parts. Copper, brass, bronze, unplated steel, stainless steel, or other metals having an electrochemical potential difference in direct contact with aluminum alloy always result in corrosion if moisture gets in the joints. Faying surfaces of metals held together by bolts, rivets, or other mechanical fastening means, usually admit moisture, hence this form of construction is particularly liable to corrosion if uninsulated.

Joints of aluminum and aluminum alloy with other metals should be reduced to the lowest practicable number. Where such joints cannot be avoided, resort shall be had to insulation, as follows:

(*a*) Copper-bearing alloys shall be cadmium-plated and painted with at least two coats of zinc chromate primer prior to assembly. The faying surfaces of the aluminum alloy must also be given two coats of zinc chromate primer. The primer must be allowed to dry. The faying surfaces must be separated by an insulator, such as canton flannel or its equivalent, impregnated with bituminous paint, soybean oil compound, or marine glue. A pure aluminum or aluminum-alloy coated spacer anodically treated and primed is acceptable for non-liquid-tight joints. The insulator should extend beyond the end of the faying surfaces approximately three-sixteenths of an inch. After assembly the standard top finish is applied.

(*b*) Steel parts must be treated and insulated in the same manner except that aluminum spray is preferred to cadmium plating. Stainless steel need not be painted but its faying surfaces shall be painted as specified above for steel parts and it must be carefully insulated from the aluminum alloy parts. The foregoing does not apply to threaded connections, pushed fit or pressed fit bushings.

As an example of trouble, copper airspeed meter tubing fastened alongside aluminum alloy streamlined struts has caused the latter to corrode at points of contact under the clamps. The method of insulation, using paint and friction tape as insulators, is a remedy.

Seaplanes of the twin-float type throw large quantities of water against the bottom of the fuselage when taxiing, and require in consequence, vigilant upkeep if the bottom longerons and athwartship struts are not to evidence excessive corrosion. The practice of coating these members with heavy grease is employed with beneficial results.

## PREVENTION OF CORROSION ON SEAPLANES

1. Marked improvement can be expected in reducing corrosion to a minimum on seaplanes by observing the following practices:

(*a*) Dip all open end struts to a depth of at least 18 inches in hot grade A rust-preventive compound; drain, and remove grease from the outside of the struts prior to assembly.

(*b*) Dip all struts other than open-end struts in hot rust-preventive compound, to a depth of 1 inch above the top bolt, or where the fitting is integral with the strut, to a depth of 3 inches.

(*c*) Coat all strut fittings attached to the hull, float, or fuselage, when being assembled as a seaplane, with hot rust-preventive compound prior to assembly of the struts.

(*d*) Coat all wing hinge pins, fittings, and metal recesses for hinge fittings with hot grade A rust-preventive compound.

(*e*) The standard paint coatings are applied prior to greasing except to moving parts or parts subjected to pounding or wear. On the latter, the paint must be omitted.

(*f*) A mixture of anticorrosive grease and beeswax in the proportion by weight of 30 percent grease to 70 percent beeswax is an acceptable alternate for the rust-preventive compound.

2. In addition to the application of grease to prevent corrosion, extensive experiments have been conducted involving the application of metal spray.

Metal spray has been used successfuly in treating steel fittings and steel struts of airplanes.

3. In addition to the application of metal spray to the parts listed in the paragraph above, the bottoms of several flyingb oats have been sprayed with aluminum. Some of these boats have been in service approximately a year since they were sprayed and reports indicate that they require a minimum of upkeep as compared with hulls not treated so and used under the same service conditions. A number of engine cylinder barrels and heads have also been aluminum-sprayed and the results have been most encouraging.

The seaplane is beached to facilitate the work, the bottom fuselage cover removed, and the members cleaned and painted if necessary, prior to the grease application. Subsequently, the aluminum bottom cowling is replaced, but only after cleaning and similar grease protection.

Proper upkeep of seaplane floats plays an important part in the preservation of operating efficiency. This is particularly important in the case of large seaplanes. The planes usually have little reserve power when carrying their full load and are, furthermore, built with a relatively low load factor. The upkeep problem, therefore, is of greatest significance in this type.

The inconvenience of hoisting seaplanes so that the entire hull will be exposed should never justify laxity with respect to inspection and elimination of corrosion. Corrosion is most likely to start around rivets and over rivet heads, along bends as at the turn of the step, and in the vicinity of wooden keels and rubbing strips. Inaccessible portions of the float interior, such as joints and recesses, should be watched carefully. When corrosion is detected, the part or parts affected must be cleaned throughly. For the removal of paint or varnish, a paint remover is used, or a suitable substitute may be made of benzol, alcohol, and paraffin wax for softening the film. The softened material then may be removed with a fiber brush, using a putty knife where necessary, care being taken not to damage the anodic surface of the aluminum alloy.

Over rivet heads and irregular surfaces, wire brushing may be necessary. After brushing or scraping, the dust should be blown off or wiped off with a dry rag. It is advisable to clean back a couple of inches in all directions from corroded areas.

The final cleaning in preparation for priming should be carried out as described previously. The surfaces must be thoroughly clean and dry before the protective coatings are applied.

*Other parts.*—Aside from the care required by the metal structure of wheel-type landing gear, the proper upkeep of the chassis requires that attention be given to oleo gear or other absorber units and the wheels and tires. The oleo gear must be maintained with oil at the proper level, and packing must be tight.

It is important that tires be maintained with their designed pressure at all times and it is advisable to jack up wheels when the airplane is not in daily use.

When they first appeared, aluminum fuel tanks gave considerable trouble in service. Corrosion failures were early reported, being accelerated as a result of vibration. Engine failures, due to gummy substances clogging lines and strainers, were common.

Corrosion has been reduced considerably by the development and maintenance of effective protective coatings. Tanks showing evidence of corrosion are treated as are other aluminum parts.

The use of rawhide strips as a lining for supporting cables or strap has been discontinued for the rawhide absorbed moisture and this kept it in contact with the tank. It is also possible that the chemicals used in treating the rawhide accelerated corrosion action. The use of waterproof oiled canvas in lieu of rawhide is now universal. It is, nevertheless, desirable to inspect the metal under the straps occasionally, clean and refinish any affected areas, and renew the straps when necessary.

While the tanks are subjected to vibration tests, vibration in operation will affect the proper tension of supporting straps and, if excessive, may cause tank failures.

Care should be taken to see that tanks rest on their supporting straps without contact with structural or other parts of the airplane. Articles of loose equipment should be carefully stowed so that they do not come into contact with tanks.

*Fueling precautions.*—The occurrence of foreign substances in tanks and fuel lines has been traced to various sources. Fuels having a high sulfur content have been found to have a corrosive effect on the interior surfaces. This is practically eliminated by the use of fuel, the specifications for which limit the sulfur content to an amount which has no appreciable corrosive effect.

The formation of metallic precipitate was traced to the precipitation in the presence of gasoline of excess flux left on the interior of tanks in the course of manufacture or repair. To eliminate this, tanks after manufacture or repair must be washed in a dilute solution of sulfuric acid.

Atmospheric moisture condensing on the interior surfaces of tanks causes the formation of aluminum hydroxide. This substance is at first a milky fluid but on aging it hardens into a spongy or granular mass. This condition obtains where tanks have been in storage for some time.

*Traps* are built into fuel systems at their lowest point to provide a depository for water and particles of foreign matter which find their way into the fuel system. At the bottom of the trap is a means of draining. THIS SHOULD BE OPENED DAILY and the flow allowed to continue until clean gasoline only is coming from the tank.

Both fuel and oil tanks are provided with *vents* at their highest point to allow ingress or egress of air in order to maintain atmospheric pressure inside the tanks. Fuel tanks are vented to the open air through vent lines running to such a point that gasoline will not be lost during inverted flight or other acrobatic maneuvers. Oil tanks are vented by a pipe running from the highest point in the tank to the engine crankcase.

It is extremely important that vents be kept open and they should be inspected frequently to this end. Stoppage of the vent in a fuel tank will cause stoppage of the fuel supply due to the lowering of pressure in the tank as the fuel is consumed, resulting in engine failure and the attendant dangers of a forced landing.

All gasoline should be strained through chamois skin or other approved strainers before entering the tanks to insure the elimination of water, and particles of rubber from the walls of the filling hose and pipe lines. The chamois skin is stretched across the mouth of a large funnel which is inserted in the tank-filler pipe. The passage of gasoline through the chamois generates static electricity which increases the potential of the strainer and funnel. In order to avoid the equalization of potential between funnel and tank by the passage of sparks, with the attendant fire hazard, careful grounding of the hose, funnel, and chamois to the tank is required.

***Miscellaneous.*** — The procedures of alinement have been discussed. Whether plumb bob or tramming method is employed will depend upon the particular circumstances.

An upkeep consideration of alinement is the necessity for not abusing turnbuckles, lock nuts, and tie rods. The use of wrenches and pliers for rotating tie rods in particular should be prohibited, since they scrape off the protective coatings and may damage the metal of the rods. A stout two-pronged fork cut from a piece of fiber is a satisfactory tool for the purpose.

Overemphasis cannot be placed on the importance of keeping the airplane clean. Dirt and oil cause the fabric to deteriorate rapidly and in the case of metal, particularly aluminum alloy, aggravate corrosion by the retention of moisture. Consequently, foreign matter should be removed on completion of the day's operation and prior to housing in the hangar. This is accomplished with heavy suds of castile soap and warm water in the case of fabric-covered surfaces. Gasoline should not usually be used. It is permissible, however, where oil is to be removed. Mud thrown on wing and fuselage fabric should not be allowed to dry but if this is impossible, the caked mud should not be scraped off but removed with warm water to avoid damage to the doped finish and fabric.

The clean airplane with cockpits free from grease and scrupulously cared for is a criterion of the pride taken by the maintenance crew in their work. There is, hence, greater insurance that the airplane has been inspected properly and will function normally. Unquestionably, the necessary cleaning has brought to their attention a large number of parts that might otherwise be overlooked, particularly if encrusted with foreign matter. The airplane is expensive compared with most automobiles yet many a pilot sits on greasy cushions, handles greasy controls, and looks at poorly maintained instrument boards which he would not tolerate in his own car. Neither should he tolerate it in the airplane.

Cleanliness of the hangar is an important factor in maintaining cleanliness of airplanes. Dirty floors, walls, and overhead get that way from inattention. The hangar should be inspected daily and cleaned at least once a week when all portable equipment and airplanes should be removed therefrom. Efforts should be directed always toward prevention of dirt accumulation since with a little attention thereto, much unnecessary removal is avoided. Taxiing in the immediate vicinity of the hangar with adverse winds blowing dust should be kept to a minimum and hangar doors should be closed to cut down accumulation of dust. When the operating line is in close proximity, a concrete apron should be provided if possible. Drip-pans should be available to place under each engine when the airplanes are hangared.

Airplanes housed in an operating hangar should have room between each, not only to facilitate inspection and cleaning, but also to obviate costly repairs made necessary where surfaces have become interlocked through bungling of handling directions. If they are not to operate for some time the wheels should be relieved of pressure by jacking up the undercarriage and the overhanging wings should be supported properly.

If quick lifting jacks are not available, small trestles or chocks may be used under the chassis so that the wheels and absorbers are relieved of all weight. Well padded horses preferably placed under the outboard interplane strut positions, are satisfactory for elimination of strain on the wing truss.

Where assembled airplanes are to be stored for any length of time they should be thoroughly clean in every respect, all control wires well greased, and lift and other wires coated with approved preservative. All fittings must be inspected thoroughly and all corrosion removed with a dull knife or scraper, prior to touching up with zinc chromate primer or other approved preservative.

Great care should be taken to see that all aircraft material is stored in a dry hangar where sufficient ventilation is possible and the material is not subjected to strong light. Wires and cables should be given their required finish. Spare metal parts, bolts, etc., should be packed in bags and dipped in neutral oil. Linseed oil must not be used, as it will dry on the bolts and make them hard to use. Hulls placed in storage after having been flown should be washed out thoroughly with fresh water and dried carefully. Metal parts should be painted or greased. Material stored should not rest on the floor, but be blocked up at least 3 inches therefrom to allow ventilation.

Storage batteries, except those employing integral shielding, should always be removed from an airplane before cleaning is started. When integrally shielded batteries are employed, it is not necessary to remove the battery, but the battery cables should be disconnected. The cable terminals should be taped while disconnected to prevent accidental contact with the battery terminals. In the event the shielded battery is located in an enclosed compartment within the airplane, the compartment and the conduit leading to the battery should be ventilated thoroughly by using compressed air before the battery is reconnected to the electrical circuit.

No electric lights or lighting equipment, or closed or open flames of any description, should be permitted near the equipment while cleaning is in process.

Smoking in the vicinity of the cleaning must expressly be prohibited, and appropriate signs posted accordingly.

All cleaned parts should be dried thoroughly before any electrical current is turned on in any circuit in the airplane.

No gasoline containing ethyl fluid (tetraethyl lead) should be used for cleaning purposes.

Adequate fire-extinguishing equipment must be kept available at all times when cleaning is being accomplished.

*A noninflammable cleaning fluid*, consisting of equal parts (by volume) of naphtha and carbon tetrachloride, has been found satisfactory for cleaning aircraft equipment. Due to the high cost of this noninflammable cleaning fluid, it is employed only when serious inconvenience or hazard would result from the use of gasoline. The mixture will not produce an explosive vapor, and will not burn in the liquid state. It is noninflammable under all conditions of use normally encountered in the cleaning of engines and other oily equipment, although a rag soaked in the mixture and exposed to the air will burn freely if ignited.

*Precautions.*—Serious toxic effects may result either by absorption through the skin, or by inhalation, whenever noninflammable cleaning fluid or carbon tetrachloride is being used for cleaning, and the following precautions should be adhered to rigidly:

The fluid should not be used except in the open or in booths equipped with forced ventilation.

Breathing the vapors must be avoided under all conditions. The equipment to be cleaned should be so located with respect to the wind or the flow of air from the ventilation system that the fumes will be carried away from the operator.

Do not place the hands in the cleaning solution. Small parts requiring brushing should be handled only by means of tongs, or some similar device while cleaning.

Do not apply cleaning fluid to heated parts as carbon tetrachloride, when heated, gives off phosgene gas, which is VERY POISONOUS.

The use of suitable spray-gun equipment, if available, is recommended for the cleaning fluids specified above. If not available, suitable brushes should be used.

## REPAIRS

*Repairs, in general,* comprise those which lie within the capacity of operating personnel. They include such structural work as repairs to fabric, doping, painting, changing of surfaces; replacements of struts and wires; checking and correcting alinement; repairs of fittings and nonvital structural members; replacement of control wires, thorough inspection and repairs of minor nature to hull and floats; replacement of tail skids or wheels and minor repairs to landing gear; adjustment of brake assembly and replacement of parts. Minor repairs to powerplant include cleaning of cowling, fuel and oil systems; replacement of hose connections; replacement or minor repairs of engine accessories; changing of propeller blades; replacement of defective instruments.

Repairs are classified as urgent or desirable, and as minor and major. *Urgent* repairs include all immediate repairs which are necessary for operating efficiency, or for prevention of deterioration. *Desirable* repairs are those which it is desirable to have made when the services of the airplane can be spared for a length of time sufficient to accomplish the work. *Minor* repairs are those which may be handled efficiently by the line-crew personnel. Such repairs include: (*a*) Patching of surfaces; (*b*) repair or replacement of ribs; (*c*) renewal of control wires; (*d*) replacement of assemblies, wings, landing gear, etc.; (*e*) repairs to or replacement of powerplant; (*f*) repair and adjustment of control surfaces; and (*g*) replacement of safety wires, cotters, etc.

*Major* repairs are those which may be beyond the capacity of line-crew personnel and are performed by a certified repair station. Such repairs include: (*a*) Major repairs to wings; (*b*) recovering of fabric surfaces; (*c*) repairs to bent, buckled, and cracked fuselage members; and (*d*) incorporation of major changes.

In general, major repairs involve a considerable expenditure of funds or require tools and technique not available ordinarily to line crews.

Holes and tears can be patched and recovering of fabric surfaces consequently obviated, provided such damaged surfaces are otherwise tight and in good condition.

Rips or tears are cross-stitched as shown in the accompanying figure before cleaning oil, dirt, and other foreign matter from the damaged area.

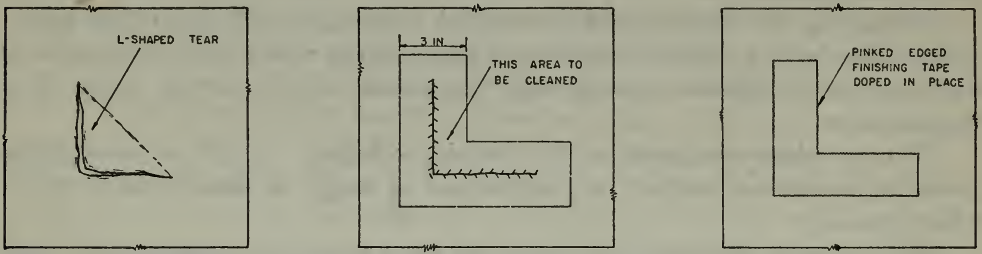


**Figure 87.—Repair of tears in fabric covering.**

Dope solvent then is applied and the foreign matter and softened dope scraped off with a blunt tool such as a putty knife over an area covering at least 1½ inches from the tear. A patch of grade A cotton tape is usually employed. For longer tears, oblong patches with square corners, frayed, about one-fourth inch all around, should be used, both owing to the area which can be covered and the adhesion afforded the edges by the fraying. Dope then is worked into and around the tear after which the patch is doped and applied over the tear with the warp of the patch coinciding with that of the surface covering as nearly as possible. After rubbing the patch with the hands until smooth, dope is applied over it and when dried, the finish coat is put on.

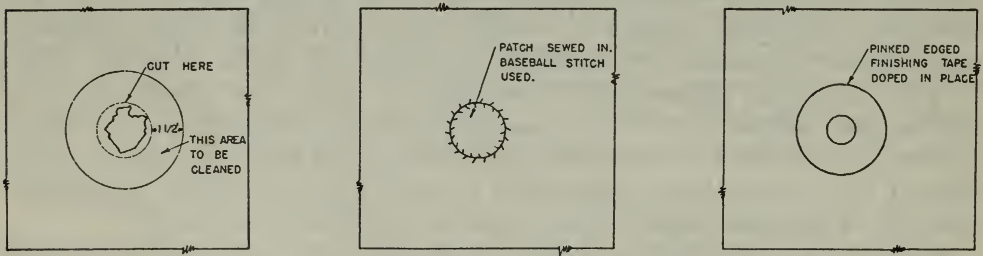

CUT HERE
1 1/2
THIS AREA TO BE CLEANED
PATCH SEWED IN. BASEBALL STITCH USED.
PINKED EDGED FINISHING TAPE DOPED IN PLACE

**Figure 88.—Repair of holes in fabric covering.**

Holes are patched in a manner similar to the above except that after the jagged edges are trimmed, a piece of fabric of the same contour as the hole is whipped into the place to fill it as shown in the accompanying figure.

Whenever possible, ribs should be repaired by the removal and replacement of all damaged members. The fabric must be cut away and laid back to enable the mechanic to get at the work. Care should be taken not to cut away the fabric any further than necessary, and it should be done in a manner which will make possible the neatest and strongest patch.

Lack of time and personnel sometimes precludes elaborate rib repairs in the field. Under these circumstances it is permissible to make repairs by lining up the warped or broken parts and retain and strengthen them with stiffeners. Otherwise, spare ribs made for such use are put in place and riveted.

Modern fuselage construction is almost entirely of the monocoque or semi-monocoque type. Irrespective of the individual variations incorporated by the various manufacturers, repair of such fuselages requires in general replacement of complete rings or portions of rings and/or replacement of reenforcement former members. The mechanical operations involved are relatively simple where the manufacture of special shapes requiring heat treatment is not involved.

Such special shapes may be stocked in limited quantities. Included in this category are the parts for rib repair previously mentioned.

Where the required parts are available, removal of rivets and damaged parts, and the installation and riveting of new parts is a relatively simple, though tedious task. Where such parts are not at hand, the services of an overhaul shop are required for the fabrication of the special shapes needed.

There are many aircraft which use the welded tubular steel type of fuselage construction, due to its lower cost and comparatively greater accessibility for maintenance, upkeep, and installation of accessories.

In practically all instances the repair work on such ships involves one of the welding processes. It should be remembered that the joints and repairs so effected may not be as strong as the tubes on which they are made, since the weld is a cast structure. The material adjacent to the weld for approximately 1 inch on either side is also weakened since it has been annealed or softened by the welding heat. The tensile strength of a joint should not be calculated as being more than 80 percent of that of the tubes.

Certain members, furthermore, owing to their method of manufacture, should not be welded. They are: (*a*) Members which depend on cold working for their strength, such as streamline tie rods; (*b*) members which depend on heat treatment for their strength, such as bolts and many types of axles; (*c*) brazed joints, since the spelter will penetrate the fused steel and weaken it.

*Straightening bent members.*—If a fuselage tube is not badly buckled or bent and is not cracked or split it may be straightened quite easily. After this has been accomplished, the straightened part will be stronger than it was originally because of the cold work done on it.

*Replacement of rivets.*—Periodic removal of aluminum alloy rivets in airplanes will be found necessary as corrosion, sustaining of shocks, and vibration cause defects about these members. Rivets to be replaced must be carefully drilled out. The holes must be examined for roughness, roundness, and if out of round should be reamed out to take a larger rivet size. Rivets should, if possible, be procured anodized. The subsequent heat treating and driving does not destroy the protection afforded by the anodic film.

Before the rivets are driven, some kinds must undergo heat treatment. Rivets in all sizes up to one-quarter inch in diameter (which are generally of 17S alloy) are heat-treated to 505° C. (940° F.), quenched in cold water, and must be driven within 1 hour after quenching. Rivets not used within this hour must be subjected to another heat treatment. No ill effects result from repeated heat treatment.

In making repairs in the field, usually it is impracticable to carry out the heat treatment necessary for the proper preparation of aluminum-alloy rivets. The use of bolts for replacement of drilled-out rivets then will be required as a temporary measure. In addition, riveting of certain portions of assemblies is impracticable because it will be found impossible to insert and hold in place any form of tool for backing up the rivet. Placing other metals in contact with aluminum alloy causes complications. The most active corrosion results from placing aluminum alloy in contact with copper or steel in salt atmosphere, although the corrosion is not as active in the case of steel. The bolts used, therefore, should be of aluminum alloy. They should be round-head bolts, and an aluminum-alloy washer should be inserted under the nut.

If aluminum-alloy bolts are not available, steel bolts may be used in an emergency, but they must be replaced at the earliest opportunity.

If, after drilling out a rivet, it is found that the metal in the vicinity of the periphery of the hole is corroded to an extent that after cleaning the hole is enlarged so that the riveting is impracticable, or if a small hole is in some manner made in the aluminum alloy sheet, repairs may be made by patching.

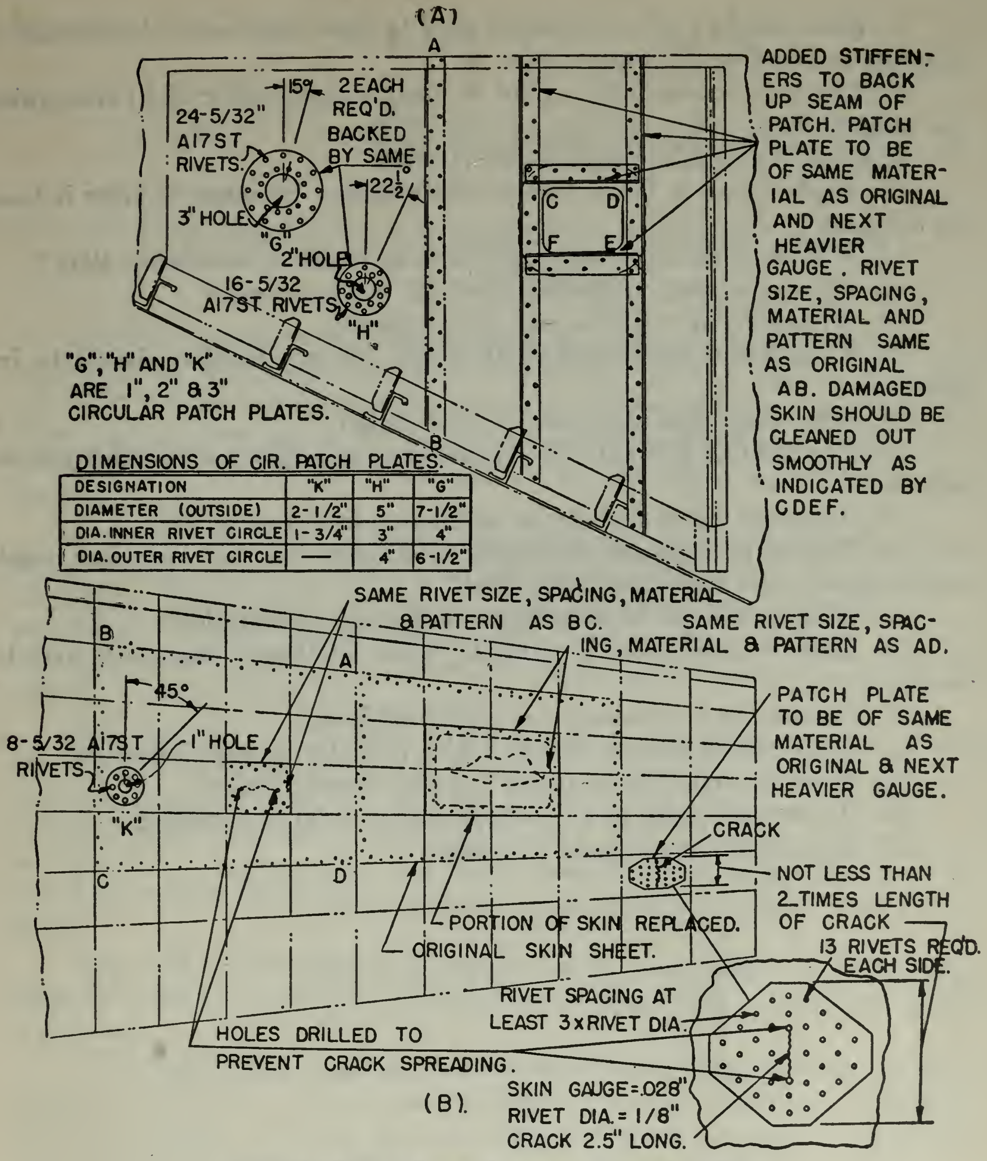
A typical patch is shown in figure 89.

The filler washer is cut from sheet to fit the hole being patched. Its function is to act as a filler and so prevent the cup washers from being subjected to excessive bending stresses. The cup washers are cut from heavy gage sheet. The lower one is of a size sufficient to allow ample faying surface all around the hole. The upper one should be of the same size as the lower, if possible, but its size and shape will be governed by the proximity of structural members.

Repair of any but small holes by the use of this type of patch is not advisable. When the area involved is at all extensive, it is better practice to remove the section affected and replace it with a new section. Large patches, of course, may be used in emergency, but the section should be replaced at the earliest opportunity as it is certain to leak and cause further trouble.

Prior to making large patches of some permanence, all deformed, cracked, or dented metal should be cut away to leave a large circular or square opening. The metal sheet is cut readily with small curved tin snips, after which the free edges should be filed to eliminate burrs and unevenness. A piece of metal similar to that of which the sheet is composed is cut to the same shape as the hole after it has been enlarged with an allowance of about 1 inch all around for rivets. After the piece has been cut to shape, the rivet line is marked around the periphery and rivet centers are indicated with a center punch. When rivet locations are indicated on the patching piece, it is placed over the hole, and holes are drilled through the sheet patch and the ruptured sheet simultaneously.

A few machine screws are used to hold the patch in place for riveting. A dolly bar is used on the inside to rivet against and rivet sets are used to give a neat round head though they may be peened flat with a hammer.


(A)
A
B
C
D
F
E
15°
2 EACH REQ'D. BACKED BY SAME
24-5/32" A17ST RIVETS.
3" HOLE
"G"
$22\frac{1}{2}°$
2" HOLE
16-5/32 A17ST RIVETS
"H"
45°
8-5/32 A17ST RIVETS
1" HOLE
"K"
CRACK
NOT LESS THAN 2 TIMES LENGTH OF CRACK
13 RIVETS REQ'D. EACH SIDE.
RIVET SPACING AT LEAST 3 x RIVET DIA.
PORTION OF SKIN REPLACED.
ORIGINAL SKIN SHEET.
(B).

ADDED STIFFENERS TO BACK UP SEAM OF PATCH. PATCH PLATE TO BE OF SAME MATERIAL AS ORIGINAL AND NEXT HEAVIER GAUGE. RIVET SIZE, SPACING, MATERIAL AND PATTERN SAME AS ORIGINAL AB. DAMAGED SKIN SHOULD BE CLEANED OUT SMOOTHLY AS INDICATED BY CDEF.

"G", "H" AND "K" ARE 1", 2" & 3" CIRCULAR PATCH PLATES.

DIMENSIONS OF CIR. PATCH PLATES.

| DESIGNATION | "K" | "H" | "G" |
|---|---|---|---|
| DIAMETER (OUTSIDE) | 2-1/2" | 5" | 7-1/2" |
| DIA. INNER RIVET CIRCLE | 1-3/4" | 3" | 4" |
| DIA. OUTER RIVET CIRCLE | — | 4" | 6-1/2" |

SAME RIVET SIZE, SPACING, MATERIAL & PATTERN AS BC.

SAME RIVET SIZE, SPACING, MATERIAL & PATTERN AS AD.

PATCH PLATE TO BE OF SAME MATERIAL AS ORIGINAL & NEXT HEAVIER GAUGE.

HOLES DRILLED TO PREVENT CRACK SPREADING.

SKIN GAUGE = .028"
RIVET DIA. = 1/8"
CRACK 2.5" LONG.

Figure 89.—Repair of holes and cracks in sheet metal covering.

## *Questions*

1. Define maintenance. Why is it important?
2. Maintenance may be divided into what four divisions?
3. Discuss each of these divisions.
4. What inspections of a certificated airplane are required?
5. Discuss the inspection of an airplane by the pilot.
6. Why is a pilot more concerned than anybody else with the integrity of an airplane?

7. What should a pilot determine prior to flight concerning the stowage of baggage and seating of passengers?

8. Why is it desirable for a pilot to make a report after flight concerning the airplane?

9. Explain how fabric surfaces are cleaned.

10. Explain how a fabric-covered surface may be renewed after it loses its tautness.

11. Why is so much attention given to corrosion of aluminum alloy?

12. What operating conditions cause the most corrosion?

13. What servicing will an oleo gear require?

14. Explain how an oleo gear with which you are familiar should be inspected.

15. What inspection is required of fuel tanks?

16. How are fuel and oil tanks ventilated on an airplane with which you are familiar?

17. How may water and dirt be eliminated from fuel tanks?

18. Why is it necessary to ground electrically the fuel hose and nozzle when airplane fuel tanks are being filled?

19. What care must be exercised in adjusting turnbuckles?

20. After a turnbuckle is adjusted what additional step must not be overlooked?

21. Discuss the importance of cleaning airplanes.

22. What care should be exercised with regard to storage batteries?

23. What care must be exercised in using cleaning fluids?

24. Discuss the patch of an L-shape tear in a fabric covering.

25. Explain the replacement of rivets.

# Chapter VIII.—MISCELLANEOUS INFORMATION

## PROCEDURE TO BE FOLLOWED IN CASE OF FIRE

### FIRE IN FLIGHT

All flight personnel should familiarize themselves with the location of fire-extinguishing equipment installed on aircraft. In the case of the smaller airplanes the fire extinguishers provided are primarily for use on the ground. These extinguishers are of the hand type utilizing carbon tetrachloride as the extinguishing medium, and are unsuitable for combating a fire outside of the fuselage in flight.

In some of the larger airplanes, hand-type carbon dioxide fire extinguishers have been provided in addition to the carbon-tetrachloride extinguisher for combating fires within the cabin. The carbon-dioxide extinguishers are particularly effective in combating gasoline and oil fires. If fabric and wood are involved, the carbon-tetrachloride extinguishers may be used in conjunction with the carbon-dioxide extinguisher.

Some types of airplanes are also provided with built-in carbon-dioxide fire-extinguisher systems, so that the engine compartments or gasoline tank compartments can be flooded with the carbon dioxide gas in case of a fire. A *distributing valve* mounted within easy reach of the pilot is set to direct the gas to the desired location and a pull handle is operated to release the gas. The operating controls of this equipment are marked clearly to indicate their method of use.

Some fuel-tank installations equipped with emergency fuel dump valves purge the tank of combustible vapors after dumping by forcing carbon dioxide in the tank.

The extinguishing equipment carried on aircraft is adequate for combating incipient fires only, and the extinguishers, regardless of type, accordingly should be put into action as soon as possible after the fire starts. In general, the following instructions apply.

*Engine, fuel tank, and amphibian hull fires.*—If the airplane is equipped with a built-in fire-extinguishing system, set the distributor valve to the proper position as soon as the location of the fire has been determined and pull the release handle.

In the case of an engine fire, and if altitude and other conditions permit, first shut off the supply of gasoline to the engine and fully open the throttle.

*Wing fires.*—Turn all switches controlling landing or navigation lights to the *off* position.

*Cabin fires.*—Use hand fire extinguisher on the fire. When using the 1-quart carbon-tetrachloride hand fire extinguisher in confined spaces, stand as far from the fire as possible. The effective range of the extinguisher is approxi-

mately 20 feet. If an electrical fire, turn main switches off. If a leakage fuel or oil line, shut off valves. If gasoline, oil, or other similar combustible liquids are involved, use hand carbon-dioxide extinguisher, if available.

### GROUND FIRES

All fires can be extinguished with the equipment installed in hangars and workshops if the fire is discovered soon enough. Personnel must know the location and have an operating knowledge of the fire-fighting equipment located in the vicinity.

If an airplane catches fire in a hangar every effort should be made to move it outside the hangar as well as to extinguish the fire.

Fire in the induction system of the engine frequently results from improper use of the hand fuel pump or throttle during starting. With the engine running opening the throttle will extinguish the fire. Otherwise, play a hand extinguisher into the carburetor intake.

*Effects of carbon-dioxide and carbon-tetrachloride fumes.—Carbon dioxide* is a nonpoisonous gas and breathing it does not affect adversely a human being either at the time it is inhaled or afterward. If the concentration of $CO_2$ gas is high enough, it will have a smothering effect, due to the exclusion of oxygen, but the quantity of carbon-dioxide gas contained in a hand extinguisher installed in aircraft is not sufficient to raise the concentration in an airplane cabin to this point.

*Carbon tetrachloride* is a volatile fluid, the gases of which when inhaled in large amounts act as an anesthetic, causing drowsiness, dizziness, headache, excitement, or loss of body feeling. Any one or all of these symptoms may occur. If small doses of the fumes should be breathed in over a period of time, probably the first effect would be drowsiness and inability to keep the eyes open, followed by sleep or perhaps headache and nausea.

Carbon tetrachloride is poisonous if taken internally. Even one-fourth of a teaspoonful may prove fatal. Inasmuch as symptoms of poisoning do not appear for several days after the fluid is taken into the stomach, any one who accidentally ingests some of the fluid should report to a doctor immediately for advice and necessary treatment.

When sprayed on a fire, carbon tetrachloride produces phosgene, a very poisonous gas. The inhalation of even a small amount may produce harmful effects and, if a sufficient quantity is taken into the lungs, the results may be fatal. Breathing the fumes when using the fluid on a fire, therefore, should be avoided.

## MOORING OF AIRPLANES

Airplanes should be moored as follows:

(*a*) Park with the tail into the wind, unless fixed mooring anchorages are available.

(*b*) Lock the controls in the cockpit as follows: (1) Elevators parallel to the ground, or, if a built-in lock control is used, as near that position as possible; (2) rudder and ailerons in neutral position.

(*c*) Lock the tail wheel in fore and aft direction.

(*d*) Place wheel chocks in front and back of each wheel.

If the airplane is equipped with hydraulic parking brakes, the brakes should be left on.

Securely anchor the airplane.

Where no fixed mooring anchorage is provided, a row of fence posts, stakes, or similar anchorage may be used. Care must be taken to use tightly secured posts at the proper points so that the securing lines will be in line with the point on the airplane to which these lines are attached.

*Precaution when lifting tail section.*—Metal-covered stabilizers are often damaged on the underside by mechanics putting their backs or shoulders under the stabilizer to lift the tail. This method of indiscriminate lifting of the tail should be avoided, and only the lift points for which structural provisions are made should be used.

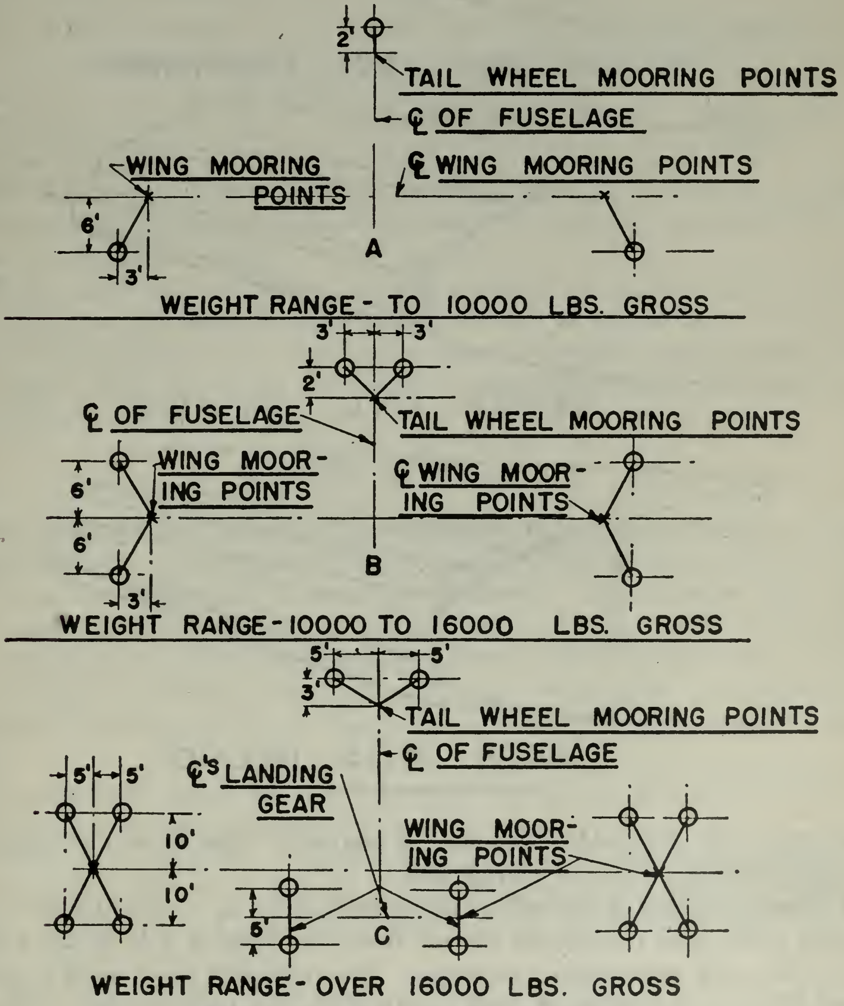
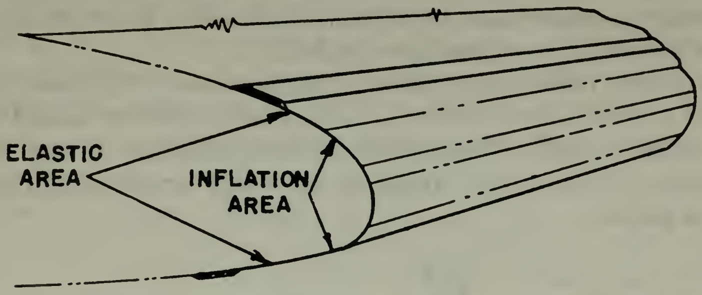


Figure 90.—Suggested mooring diagram for aircraft.

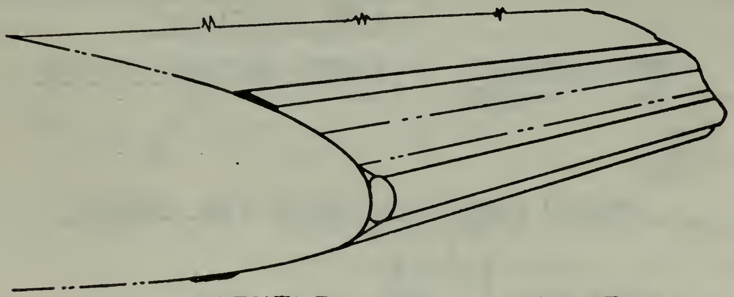
## ANTI-ICING AND DE-ICING EQUIPMENT

The accumulation of ice on the airplane wings, tail surfaces, radio loop and masts, is removed by a *de-icing system* consisting primarily of inflatable rubber shoes attached to the leading edges of these units and periodically inflated by air from the exhaust side of vacuum pumps.

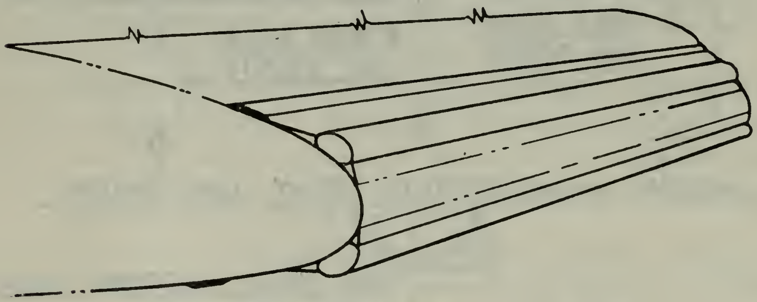
The inflatable rubber shoes for wings and very large tail surfaces contain several independent air cells. The shoes for normal-sized tail surfaces usually contain two cells manifolded together at one end. The shoes for radio loops and masts usually consist of a single cell.



DE-ICER SHOE NOT FUNCTIONING



CENTER CELL INFLATED



OUTER CELLS INFLATED

Figure 91.—De-icer shoes.

Periodic inflation of the cells is accomplished by an electrically driven distributing valve that distributes the air from the exhaust side of the vacuum pump to the cells in a suitable sequence. The inflatable shoes on the wing are inflated in the order in which they occur aft of the leading edge. The cells of the other shoes all are inflated simultaneously.

The pressure relief valve is set at 7 pounds per square inch, which is the air pressure in the cells when inflated. A three-way valve is provided to by-pass the air from the vacuum pump when the de-icing system is not in operation. When more than one vacuum pump is used to supply air for the de-icing system, air check valves are provided so that the system will continue to function in case one vacuum pump fails.

As the operation of the de-icing system on air-foils affects the aerodymanic characteristics of the airplane, the system should not be operated while landing the airplane or in any other attitude of flight in which the airplane approaches the stalled condition.

*Anti-icing equipment.*—The formation of ice on the propeller blades is prevented by a propeller anti-icing system. The system consists of a supply of anti-icing fluid, a pump for metering out the fluid, and a *slinger ring* for distributing this fluid over the propeller blades. Centrifugal force on the water particles as they strike the coated surface of the blade is sufficient to prevent the ice from building up, as the coating of fluid serves to lower the adhesion of the ice particles to the metal.

The metering pump is of the dual diaphragm, electrically operated type and has a maximum capacity of 10 quarts per hour. The speed of rotation, and hence the capacity, of the metering pump is controlled by a rheostat.

The slinger ring is merely a channel collector ring with a delivery tube for each blade.

The fluid is a mixture of 85-percent ethyl alcohol and 15-percent glycerine. Approximately 2 quarts per hour of this fluid is required for each propeller to prevent the formation of ice.

*Engine carburetor.*—Due to the heat necessary to vaporize the fuel being extracted from the air in the carburetor, as well as the pressure drop in the venturi, ice may form in the carburetor when the outside temperature is relatively high. The carburetor air heater is used to eliminate or prevent the formation of ice in the carburetor.

## WEIGHT AND BALANCE

Since the proper balance of an airplane is essential to stability and good handling qualities, the following paragraphs regarding weighing procedure and check of center of gravity location are included. It is essential that a pilot make sure that the loading of an airplane comes within the limitations which are set up by the airplane manufacturer and the Civil Air Regulations. In case of any doubt concerning the weight and balance of a plane, the owner should correspond with the factory to assure himself of the safety of the airplane as loaded.

The example which follows in the included material will illustrate how simple weight and balance computations are made.

*Weighing of aircraft.*—Procedure: When it is necessary to obtain the actual empty weight of an aircraft the following procedure should be followed:

(*a*) Aircraft should always be weighed inside a closed building to prevent error in weights due to wind.

(*b*) Determine that the scales to be used are reliable.

(*c*) Determine that each scale is level and balanced at zero.

(*d*) Ascertain that fuel tanks are empty.

(*e*) Oil tank may contain either the number of gallons noted on filler cap or be drained. When weighed with full oil the actual empty weight equals the actual recorded weight less the weight of oil (gallons multiplied by 7.5). All reports should show if weights include full oil or oil drained.

(*f*) Radiators of liquid-cooled engines and water coolers should be full.

*Weighing for empty center of gravity location.*—When the empty center of gravity location is to be found, the aircraft must be weighed and the location computed as follows:

(*a*) The aircraft must be in a level flying position when weighed.

(*b*) The oil must be drained. The tank may be full provided the computations account for the added weight. Always show such weight as "empty plus—gallons of oil."

(*c*) Record the weights and dimensions ($x$ and $y$) indicated in figure 92 and compute the center of gravity as shown.

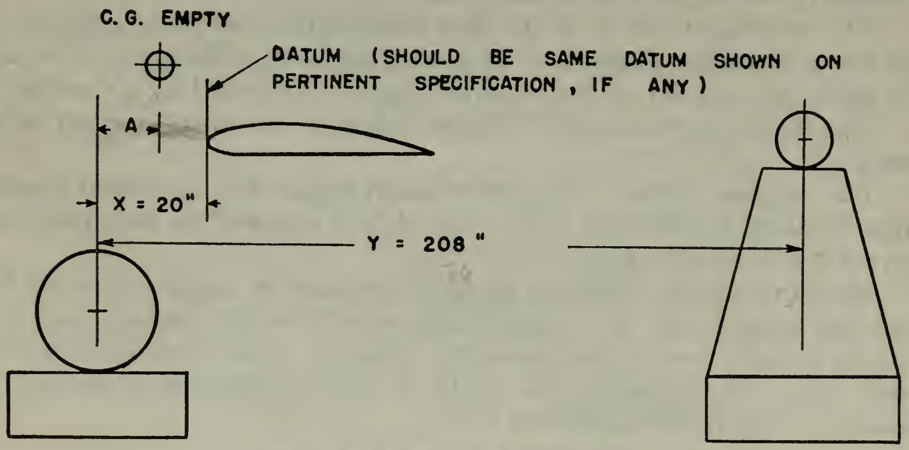

C. G. EMPTY
DATUM (SHOULD BE SAME DATUM SHOWN ON PERTINENT SPECIFICATION, IF ANY)
A
X = 20"
Y = 208"

Figure 92.—Typical weight empty diagram.

| | Scale reading | Tare | Net |
|---|---|---|---|
| | | | *Pounds* |
| Right wheel | 1, 238 | 0 | 1, 238 |
| Left wheel | 1, 238 | 0 | 1, 238 |
| Tail wheel | 213 | 24 | 189 |
| Total weight loaded | 2, 689 | 24 | 2, 665 |

Center of gravity empty is *aft* of wheel centerline $=a=$ net tail wheel scale reading times $y$ in inches divided by empty weight $=\frac{208\times 189}{2665}=14.75$ inches. Center of gravity empty is forward of datum $=x-a=20-14.75=5.25$ inches.

*Weighing to determine if approved limits are exceeded.*—In lieu of computations, the effect of a change in equipment on the center of gravity may be determined by weighing the airplane as follows:

(*a*) The aircraft must be in a level flying position when weighed.

(*b*) Load the airplane with all items of useful load (fuel, oil, passengers, crew, and baggage) for that center of gravity position affected by the change in equipment; that is, for the most forward center of gravity condition include all items forward of the most forward center of gravity limit and only those items aft of that limit which are absolutely necessary, such as minimum fuel.

(*c*) If the proposed equipment is not installed, an equal amount of ballast should be added at same location prior to weighing.

(*d*) Record the weights and dimensions and compute as noted in paragraph above.

### *Case I*

A single item of equipment $W_1$, added at an arm $X_1$, which is *between* the approved center of gravity limits $A$ and $B$.

In the forward center of gravity condition $W_1$ is aft of $A$ and tends to make the airplane more tail heavy, while in the rearward center of gravity condition $W_1$ is forward of $B$ and tends to make it more nose heavy, therefore, the balance is satisfactory.

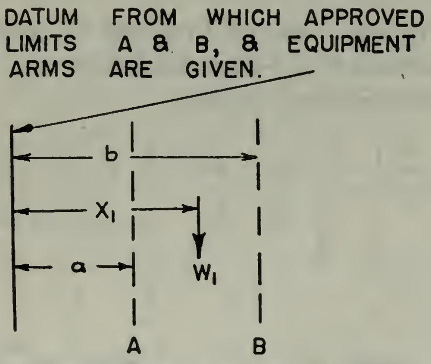

DATUM FROM WHICH APPROVED LIMITS A & B, & EQUIPMENT ARMS ARE GIVEN.
b
X₁
a
W₁
A
B

**Figure 93.—Loading diagram for case I.**

Datum from which approved limits $A$ and $B$, and equipment arms are given is shown in figure 93.

$a$=Forward limit in inches as per specification.
$b$=Rearward limit in inches as per specification.
$x_1$=Equipment arm in inches as per specification.
$W_1$=Equipment weight in inches as per specification.

Example.—Operator desires to install two special type pilot chairs in a Stinson SR–8D.

C. A. A. Specification No. 609.

Center of gravity limits (landplane) are 17.1 and 27 inches aft of datum.

Item 26 is at 18 inches, i. e., between 17.1 and 27 inches, hence the balance is satisfactory.

### *Case II*

(*a*) A single item, $W_1$, is added aft of $B$, or (*b*) a single item of standard equipment, $W_1$, is removed forward of $A$. Determine baggage reduction necessary to prevent center of gravity moving aft of $B$, i. e., exceeding approved limit.

$$\text{Baggage reduction} = \frac{\text{Weight of item by distance to rear center of gravity limit,}}{\text{Distance from baggage to rear center of gravity limit}} \text{ or}$$

$$(1)\ Br = \frac{W_1(x_1 - b)}{c - b} \text{ (item added aft of B, fig. 2).}$$

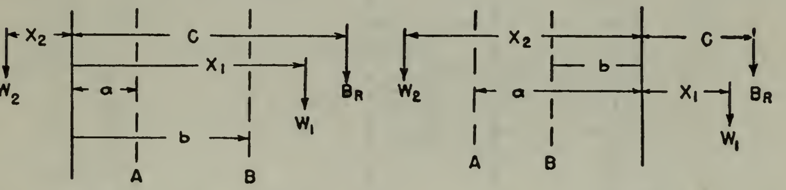
$$(2)\ Br = \frac{W_2(x_1 + b)}{c + b} \text{ (item added aft of B, fig. 3).}$$

$$(3)\ Br = \frac{W_2(x_2 + b)}{c - b} \text{ (item removed forward of A, fig. 2).}$$

$$(4)\ Br = \frac{W_2(x_2 - b)}{c + b} \text{ (item removed forward of A, fig. 3).}$$

Example.—(*a*) Operator desires to install RCA transmitter model AVT–7 in a Waco YKS–6 licensed as a 5-place landplane.

From C. A. A. Specification No. 533.



DATUM
WHERE FORWARD OF CENTER OF GRAVITY LIMITS (AS MOST MONOPLANES)

DATUM
WHERE AFT OF CENTER OF GRAVITY LIMITS (AS MOST BIPLANES)

**Figure 94.—Loading diagram for case II.**

Center of gravity limits are 14.4 inches (*a*) and 2.4 inches (*b*) *forward* of lower wing leading edge.

Item 49, RCA transmitter, is 26 pounds ($W_1$) at 31 inches ($x_1$). Baggage is at +49 inches (*c*).

$$(2)\ Br = \frac{26(31+2.4)}{49+2.4} = \frac{26 \times 33.4}{51.4} = 16.9 \text{ pounds.}$$

Reduction in baggage is therefore 17 pounds.

Allowable baggage is therefore 70 [1]—17=53 pounds.

Example (*b*) operator desires to remove generator which is included in standard equipment.

The arm will not appear on the specification so it will be necessary to measure approximately the distance from the center of gravity (of the generator) to the datum.

From C. A. A. Specification No. 533.

Item 3, generator weighs 13 pounds ($W_2$).

---

[1] Unless manufacturers' weight and balance report has substantiated more.

Measured arm is approximately −56 inches ($x_2$).

$$(4)\ Br=\frac{13(56-2.4)}{49+2.4}=\frac{13\times 53.6}{51.4}=13.6\text{ pounds.}$$

Reduction in baggage is therefore 14 pounds.
Allowable baggage is therefore 100−14=86 pounds.

## GENERAL MAINTENANCE

Discrepancies in the flight characteristics of new airplanes of the same type and model number are comparatively few in proportion to the number designed and built. Occasionally an airplane will be found which has a marked tendency to "fall off" on one wing or the other when it is completely stalled. This is quite often due to movement of the jig blocks which are used as a pattern in construction of wood ribs. In this case it will be possible to adjust the rigging of the aircraft in such a manner that it will fly quite well at cruising speed but will have a tendency to fall off to one side or the other when stalled. Obviously this is due to lack of uniformity in the contour of the ribs, and there is little that can be done about it unless they are replaced. The shape of the ribs may be checked by means of a large pair of calipers as to depth and a long straightedge as to uniformity of alinement.

Very little difficulty has been experienced in this respect with metal ribs due to the fact that they are usually stamped in a special jig, and do not readily change shape. In any case, when repairs are made the uniformity of airfoil shape should be closely checked after completion of the operation.

Discrepancies have also occurred due to repairs made necessary by damage to either wing, which may also be checked in the manner outlined above. In either case there is a possibility that the shape of the aileron has been altered or the hinges installed with their centerline too high or too low, thereby causing a change in airflow which might create an unnatural negative pressure on one side of the surface and a positive pressure on the other. Imperfections in the arrangement of the covering in the gap between the aileron and the subspar might also affect the position maintained by the aileron in flight. The foregoing might not necessarily make the ship wing heavy, but one aileron might ride high and the other low in flight

Considerable difficulty has been experienced in some instances after an airplane has been nosed over although the damage may have appeared ever so slight. In every such case the engine mount should be checked for alinement by trammeling, or measuring like distances on structural members of the mount. Obviously the mount should also be checked for dents, cracks, and failures at the fittings. The fuselage covering should also be closely inspected for wrinkles which might indicate damage to longerons, vertical members, or other structural members of the fuselage. If the fuselage is warped out of shape, it may be checked by trammeling with trammel points attached to a long member, or distances of like dimensions may be checked with a steel tape. The most accurate method is to strip off the covering, mount the fuselage on horses and attach plumb lines in a wire located above and parallel to the longitudinal axis, and then measure to the plumb lines from stations having equal dimensions.

In cases where an engine of approximately 100 horsepower has been removed from a biplane and one of 200 horsepower or more installed in its place, the aircraft may have a tendency to be nose heavy in power-off flight, while in cruising flight it may function normally.

In this case the stagger is increased to compensate for the additional weight of the larger engine in order to obtain proper fore-and-aft balance in flight. The adjustments are governed by trial and error during test flying and while the additional blast from the increased pitch of the propeller blades driven by the higher-powered engine is present on the horizontal tail surfaces. Thus proper power-on balance is attained, but the power-off balance is impaired. Usually the condition can be remedied by "canting" the engine or tipping it slightly forward at the top. The amount will vary and should be obtained from the aircraft manufacturer. By thus canting the engine, the slip stream or blast is moved upward and less stagger will be required in cruising flight, which will permit better power-off balance while gliding.

After a considerable number of hours of service the elevator or "flipper" control-surface hinges will become worn and develop play. As long as the play is not excessive it is not generally considered critical. In fact some of the faster aircraft have a slight clearance in the hinges to prevent stiffness of the flipper controls which might cause pitching in flight.

If the flippers are fitted with adjustable tab controls in order that the pilot may compensate for variation in loading of the aircraft, both the tabs and the cables should be checked for play quite frequently. In some cases, if slack develops the flippers will "flutter," which may result in disintegration of the tail group and a serious accident.

When it is necessary to change a propeller, the design numbers and other information stamped on either the hub or the blade should be used in ordering a replacement unit. If this information is not available, the following items should be taken into consideration:

1. Must be approved type.
2. Not listed on reject list (manufacturing or C. A. A.).
3. In good condition (if used).
4. One-inch clearance on structure (minimum).
5. Adequate ground or water clearance (9 inches, landplane; and 18 inches, seaplane).

In measuring the ground clearance of a propeller on a land plane, the propeller should be placed in the vertical position. The aircraft should be in level flying position, fully loaded, and struts and tires in normal condition of inflation. The seaplane should be resting in normal position on the water and fully loaded. The clearance is measured between the lower propeller tip and the ground or water as the case may be.

Occasionally a chronic condition of ground looping will be found in an airplane. It may ground-loop consistently to one side or may vary, depending on which way it is permitted to start. This condition may be caused by improper inflation of air strut or tire on one side of the airplane landing gear, or by the parking brake dragging. Also one side of the landing gear or the tail skid or wheel may not be correctly alined.

The dimensions of the landing-gear struts at various points on the two sides may be compared to determine whether or not the landing gear may have been damaged and repairs improperly made. In most ships, the wheels are toed in, or closer in front than at the rear. They are also cambered, or closer together at the bottom than at the top, especially when the ship is lightly loaded. Before checking the toe-in and camber, the airplane should be moved to a level surface, such as a hangar floor, and then rolled forward in order that each side of the gear may take a normal position. The toe-in may be checked by measuring from the center of the tires, front and rear, and the lesser measurement in front checked against the manufacturer's specifications. Camber may be checked by placing a carpenter square on the floor and alining it along the center line of the wheel, adjacent to the end of the axle. The square should touch the wheel at the top and measurements be taken at the upper and lower portion of the rim adjacent to the square. The difference in the distances from the square to the rim at the bottom and the top is the approximate camber. This should also be checked against the specifications.

The central position of the tail stern post may be determined by measuring from its lower end to corresponding points on opposite sides of the fuselage near the landing-gear attachment fittings. This is to check the fuselage for general alinement. The tail wheel or skid may then be checked on both sides from the stern post or a forward fuselage station to see that it is properly centralized.

Some difficulty has been experienced from water appearing in gasoline tanks under circumstances for which there seemed to be no explanation. In two cases it was said to be due to the airplanes being stored at night in a warm hangar with the fuel tanks partially full. The temperature in the hangar was said to fluctuate throughout the night because of occasional firing of the furnace by the watchman on duty, a uniform temperature being unnecessary since the maintenance crews were not active. It was claimed that when the ships were stored with fuel tanks full that the difficulty was eliminated.

As a final word, it should be emphasized that the pilot's own safety as well as that of his passengers is dependent to a large degree on the proper condition and functioning of his aircraft. Therefore, as regards maintenance and repairs it is his responsibility to see that the work is done properly and by a competent mechanic. In this, as in actual flying, there is no room for guess work. The pilot, in exercising this responsibility, should assume the task seriously and painstakingly, even at the risk of being called "fussy" by maintenance and repair personnel.

### *Questions*

1. Outline in detail what fire-prevention precautions should be taken with regard to (*a*) hangar, (*b*) an airplane on the line, and (*c*) an airplane in flight.

2. Make up an outline of the procedure to be followed in case of fire in each of the above cases.

3. What precautions must be exercised in the use of carbon tetrachloride as a fire-extinguishing fluid?

4. Explain how an airplane should be moored when stowed overnight in the open.

5. What care must be exercised when lifting the tail of an airplane?

6. Distinguish between anti-icing and de-icing equipment.

7. What precautions should be exercised in the operation of de-icing equipment?

8. Explain the operation of the Slinger ring anti-icing equipment.

9. Explain the operation of de-icing equipment.

10. How may ice be prevented from forming in an airplane carburetor?

11. Discuss the weighing of a plane with which you are familiar.

12. What weight per gallon is figured for oil and for gasoline?

13. How is the empty center of gravity location determined?

14. Work out a similar problem for an airplane with which you are familiar.

15. How is the location of the center of gravity affected by adding a radio set in the baggage compartment behind the rear seat?

16. Work out a problem as applied to an airplane with which you are familiar in accordance with cases I and II.

17. Give one reason why an airplane which normally flies satisfactorily will fall off on one wing consistently when stalled?

18. How may the contour of ribs be checked after the wing has been assembled and covered?

19. Name some of the items which should be checked after an airplane has been nosed over.

20. Explain what circumstances might cause an airplane to be balanced with the power on but extremely nose heavy with the power off.

21. List five items which should be checked when a new propeller is installed.

22. Explain what is meant by toe-in and camber as applied to wheels.

23. Mention one possible cause of water in fuel tanks.

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